spaceflight

Published by
The British Interplanetary Society

JANUARY 1986
VOLUME 28 No 1

New Astronomy Books From

CAMBRIDGE

Supernovae

PAUL MURDIN and **LESLEY MURDIN**

This well-illustrated volume will make fascinating reading for any astronomy enthusiast. It begins by capturing the flavour of ancient astronomy with a consideration of historical supernovae and then goes on to divulge a wealth of scientific information on supernovae, pulsars and nucleosynthesis in an entertaining and non-technical way.

185 pp. *1985* *0 521 30038 X* **£12.95 net**

Astrophotography for the Amateur

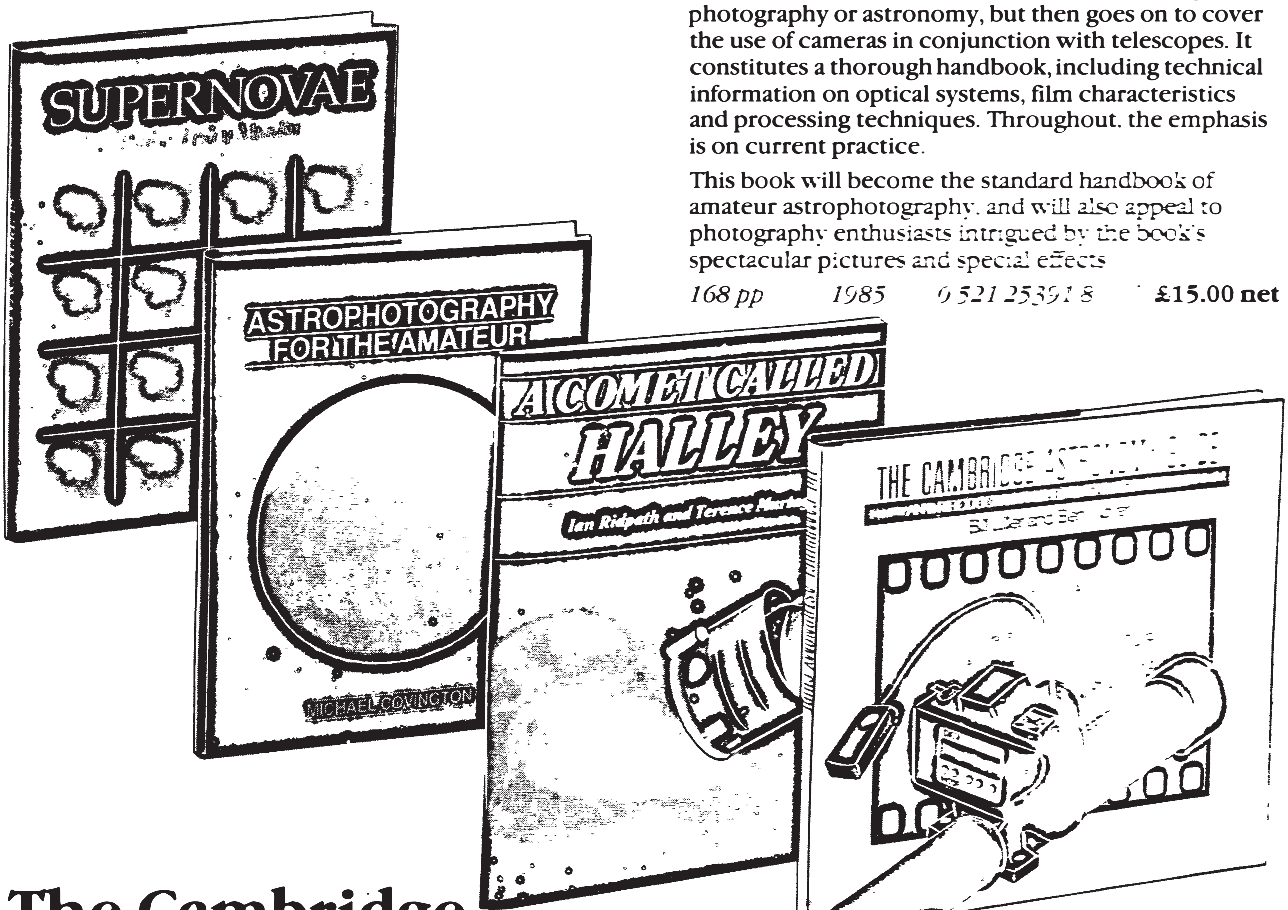
MICHAEL A. COVINGTON

Astrophotography for the Amateur describes the methods of capturing stars, galaxies, planets, the Moon, the Sun, comets, meteors and eclipses by photography using equipment readily available to the amateur astronomer.

It starts from basics and assumes little knowledge of photography or astronomy, but then goes on to cover the use of cameras in conjunction with telescopes. It constitutes a thorough handbook, including technical information on optical systems, film characteristics and processing techniques. Throughout, the emphasis is on current practice.

This book will become the standard handbook of amateur astrophotography, and will also appeal to photography enthusiasts intrigued by the book's spectacular pictures and special effects

168 pp *1985* *0 521 25391 8* **£15.00 net**



The Cambridge Astronomy Guide

An Introduction to Practical Astronomy

WILLIAM LILLER and **BEN MAYER**

The Cambridge Astronomy Guide is intended for lovers of astronomy who wish to do more than just look at the night sky or marvel at glossy pictures of it. Astronomy, more than any other science, offers amateurs the opportunity of making lasting contributions. This guide explains in simple, non-mathematical terms how you can take stunning star photographs and then use the valuable information collected to push forward the frontiers of astronomical science.

176 pp. *1985* *0 521 25778 6* **£13.95 net**

A Comet Called Halley

IAN RIDPATH and **TERENCE MURTAGH**

This handy, highly-illustrated book is ideal for any general reader curious to know more about one of the most mysterious phenomena in the Universe. The book describes the Comet, its origins and history, tells how it was discovered and explains where best to view it and how to photograph it. The text is complemented by diagrams, sky charts and computer animation sequences, many in colour, to make an extremely readable companion for anyone interested in this unique cosmic visitor.

48 pp. *1985*
0 521 31282 5 **Paperback £2.95 net**

Cambridge University Press
The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU, England

Editor:
G V Groves

Managing Editor:
A. Wilson

Assistant Editor:
L. J. Carter

CONTENTS

COVER

Neptune as seen from Triton, a painting by B.I.S Fellow David Hardy. *© D.A. Hardy*

spaceflight

A Publication of The British Interplanetary Society

Founded 1933 *Incorporated 1945*

VOL. 28 NO. 1 JANUARY 1986 *Published 15 December 1985*

BETTER LATE THAN NEVER

The UK Government's move to set up the British National Space Centre, announced on November 20, is to be wholeheartedly welcomed. The Society advocated the need for an Authority to oversee UK Space policy and management in a Special Memorandum to the Government in 1972 and has since repeatedly urged such a course of action. Other voices have joined the call, including that of a Parliamentary Select Committee and the Royal Society. The case for such a move has always been overwhelming.

US space programmes have abundantly demonstrated the need for high-level planning, management, organisation and decision-making in order to realise the potentialities of the Space enterprise: an Authority is needed with ready access to the pinnacle of political power.

In 1958, the NASA was formally brought into being by the US Government and for over 25 years has championed US Space endeavours. In France, the realities of the situation were rapidly grasped leading to the establishment of CNES in 1961. Both NASA and CNES have continued to develop expanding roles as new Space horizons have appeared and new frontiers been reached. They have sponsored the development of new technologies, new areas of science and new applications bringing expansion to industry, particularly their aerospace and computer industries, and in turn benefits to their nations through the effective employment of national resources and skills.

In the UK, Space has been the Cinderella of diverse government Departments each dominated by primarily 'non-space' interests. A little support may have been provided here and there only to be dropped the next time round. Good ideas have readily gone by the board and promising Space initiatives have been started and then petered out in a climate of decreasing interest and lack of political will.

A case in point is the UK 'Black Arrow' satellite launch vehicle which was allocated to the scrap heap on successfully launching its first satellite into orbit. Regrettably, we have seen the spending of a not inconsiderable budget, now running at £100m per annum, with relatively little to show in the way of permanent space achievement and the will to capitalise on it.

The present situation cannot be changed overnight but a start has been made. The newly-appointed Director-General of the British National Space Centre, Roy Gibson, brings with him a wealth of experience from his former position as Director-General of the European Space Agency and a good measure of personal vitality and realism. We wish him every success in his new Office, recognising that much needs to be done and that many complex administrative and technical decisions lie ahead.

The UK now has the opportunity to put its house in order in regard to Space, so that nationally it is fit and equipped to move into the international Space arena with attractive and saleable products. Lost opportunities cannot be regained, but the future is there to be won. The present time is a particularly auspicious one for Space with the US Space Shuttle at operational status, the Space Station programme underway and new advanced ideas, such as HOTOL on the table if not on the drawing board. Opportunities are there to be grasped. Better late than never.

NEW BRITISH SPACE INITIATIVE

The new British National Space Centre is getting down to the business of coordinating the UK's hitherto fragmented space effort. *Clive Simpson* reports on the latest developments.

Staff at the UK's new National Space Centre are working on a long term space strategy for the country following the recent appointment of its first Director-General, Mr. Roy Gibson.

Based in London, he will have the help of 30 civil servants to develop the country's first ever coordinated space policy over the coming months.

The British National Space Centre (BNSC) is seen as a counterpart to similar agencies in Germany and France which have already achieved a high degree of success in establishing a sound industrial and policy-making base for their respective countries.

Mr. Gibson, a former head of the European Space Agency (ESA), described his appointment as "a great privilege" and agreed that one of his first tasks would involve drawing up a coordinated space plan for the UK.

"I am convinced that for the amount of money we spend and for the number of people in this country involved in space we can have more impact than we do," he said.

Confirming the appointment of Mr. Gibson in London on November 20, the Minister of Industry and Information Technology, Mr. Geoffrey Pattie, described it as "a very important time" for space, both on the European scene and for the space industry in Britain.

He said the space centre was needed to bring into focus Britain's space activities which were previously the responsibility of separate government departments.

"It is a clear recognition in Government circles of space as a leading-edge technology generator and is an exciting area for Britain to be involved in."

Mr. Pattie cited the need to develop a longer term space strategy, taking into account the needs of industry, science and other civil and defence users of space.

"In Britain, as elsewhere, we have a growing range of such users. As they have become more aware of the benefits offered to them by space it is important to establish a focus to which they can turn for advice and technical support. They will be able to influence the programme of the space centre by making their own financial and in-kind contributions.

Mr. Gibson was one of the principal architects of the European Space Agency and became the first Director-General on its inception in 1975.

He was responsible for the management of space programmes amounting to £500m a year and since leaving ESA in 1980 has been a consultant and director of several British and multi-national space companies.

Mr. Gibson is a Fellow of the British Interplanetary Society.

"The gains we look for include a better balance between technology 'push' and user 'pull'. The centre will also facilitate the development of joint programmes in areas such as space infrastructure, of interest to the entire space community in Britain," stated Mr. Pattie.

Currently Britain spends £100m a year on space activities, £80m of which goes to ESA. The remaining £20m is channelled through various government departments to the scientific world. But with further ESA participation in the American-led international Space Station programme now likely the BNSC will be looking for a substantial funding increase over the next few years.

Space centre staff are already working on the development of a British space plan to take the country into the 1990's and will be drawing on experts at the Royal Aircraft Establishment, Farnborough, and SERC's Rutherford Appleton Laboratory near Oxford.

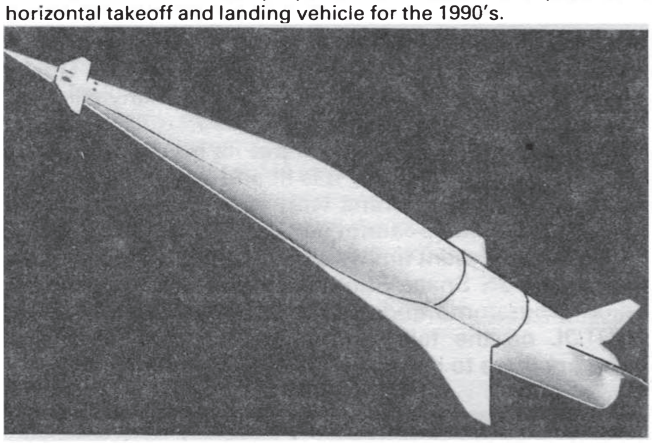
In addition, Mr. Pattie is hoping for a significant input from companies throughout the country which are involved in all aspects of the aerospace business.

One programme which Mr. Gibson and his team will soon have to consider is the proposal from British Aerospace for a horizontal takeoff and landing vehicle, known as HOTOL. Mr. Pattie said discussions were currently taking place with British Aerospace and these were about to address the "proof of concept" stage.

Headquarters for the BNSC will initially be in Millbank, London, and the 30 staff there will be interacting with others at various scientific establishments and with the three major government departments involved – the departments of Transport and Industry, Education and Science, and the Ministry of Defence.

Plans for a national space centre were first announced by the Government in January 1985 after ministers decided there was a need to improve the UK's development of space technology and coordinate policy more effectively.

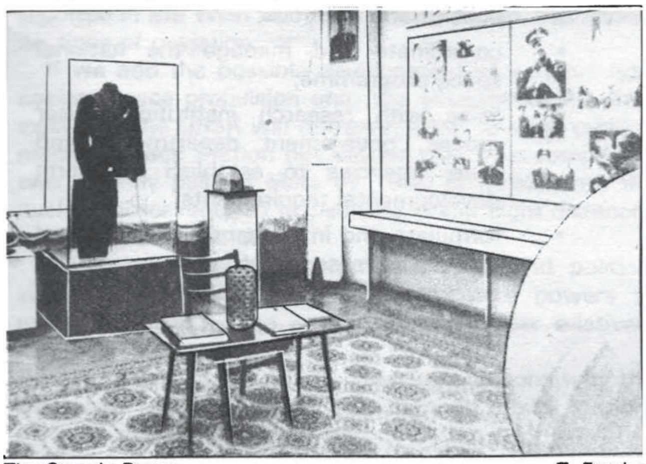
A model of HOTOL, the proposal from British Aerospace for a horizontal takeoff and landing vehicle for the 1990's.



The Gagarin Museum

Sir, My visit to the Gagarin Cosmonaut Training Centre (May *Spaceflight,* p.196) provided a chance to tour the Space Museum in the public area of Star City, dedicated to Yuri Gagarin. About 90,000 people visit it every year and almost 750,000 people have done so since it was opened in November 1967.

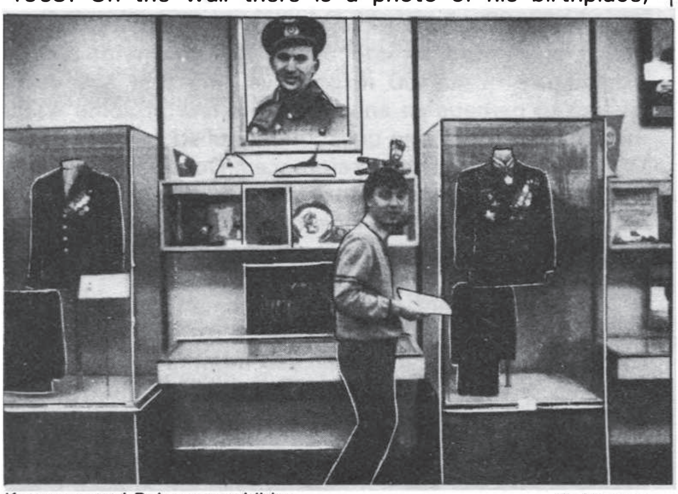
There is an intimate atmosphere in the 'Gagarin Room.' His uniform is adorned with his many medals and awards. Memorabilia include personal documents found at the crash site [the cosmonaut was killed in a 'plane crash in March 1965 *-Ed*] including a photo of Korolev from Gagarin's wallet. There is a small box of soil from where the aircraft came down and photographs of his birthplace.



The Gagarin Room. *T. Furniss*

Another room contains gifts and souvenirs from all the Intercosmos flights; newspapers, badges, flags, stamps, signatures and Salyut items such as notes, memos and food packages. Included are the uniforms of Komarov and Belayev and many of their personal belongings. The flight suits of the Dobrovolsky crew can also be seen. There are watches, medals, a photographic gallery of all the cosmonauts, first day covers, the letters delivered to Soyuz 4 by Soyuz 5 and flight pens. Many items are gifts from the US astronauts, including a tribute from Armstrong and Aldrin, Borman's Apollo 8 watch, Carpenter's Sealab watch, a plaque that went to the Moon, Apollo-Soyuz documents and some books.

Nearby is a faithful reconstruction of Gagarin's office. On his desk are drafts of a speech he was writing, invitations and letters. The diary is opened at 27 March 1968. On the wall there is a photo of his birthplace,



Komarov and Belyavev exhibits. *T. Furniss*

Smolensk, taken on the day that he flew into space. In the wardrobe is his military overcoat and cap. The bookshelf is packed with documents. The clock on the wall has been stopped at 10.31 a.m., the time of his death. Before they leave for the cosmodrome, cosmonauts visit his office, which they call their first launch site.

The final museum room contains the first Vostok simulator, spacesuits worn by Gagarin, Titov and Tereshkova, Leonov's EVA suit, the Soyuz 4/5 EVA suits and Romaneknko's Soyuz suit. The Soyuz 4 capsule is here, as are the ASTP docking collar and the drogue 'chute from Soyuz 37. ASTP memorabilia include Leonov's suit and badges, some gloves and space food. There are also photographs from each mission.

TIM FURNISS
Epsom, Surrey

Not Mars?

Sir, I was concerned by the emphasis on a manned Mars exploration mission in the medium term as discussed in the November 1985 issue of *Spaceflight.* It is reminiscent of the Apollo missions which, though technically brilliant, provoked reaction against the huge expenditure for a minumum return. The space programme is often viewed as an expensive toy rather than an investment in the future of humanity. If a space station/transportation system had been attempted *before* Apollo then the expense might have been less and a permanent base built on the Moon, rather than having a few men spend a few days there. It is not enough for space to be exhilarating: we must have rewards and plan for the long term.

It is *much* more important to get a strong presence on the Moon than a man on Mars. It is said that a manned Mars expedition would give an opportunity for international cooperation and that we should go to Mars because 'people want something to look forward to.' We can do both of these on the Moon and get two advantages:

1. a return on capital for Earth now, and
2. a foundation for future missions to build on.

Future deep space expeditions to the asteroids and Jupiter would have similar promise for long term colonisation, by getting materials from the asteroids and water and helium-3 from the Jupiter system. We must avoid thinking of Mars as the prime option when there are many investments that need to be done first. We need the vision of the enthusiast to be combined with a degree of pragmatism to avoid extravagance.

JOHN PAHL
Canterbury, Kent

The 'Soviet' Vegas

Sir, I wish to point out that the Vega craft carry a number of instruments developed and built in countries other than the Soviet Union so they can truly be termed *international.*

MICHAEL BEÖTHY
ing. on telecommunications
Intercosmos Secretary Office
Hungarian Academy of Sciences

A Space Policy for Australia?

Sir, Following the first Australian National Space Symposium in March 1984, the Minister of Science, the Hon. Barry O. Jones invited the Australian Academy of Technological Sciences to form a Working Party to prepare a report on space science and technology for Australia. The report, entitled 'A Space Policy for Australia,' was published last June. The Working Party, chaired by Sir Russel Madigan, made 16 specific recommendations:

1. Australia should, as a matter of urgency, establish a national space policy to facilitate the achievement of an appropriate industrial, technological and scientific structure for Australia's participation in space.
2. In the communications market Australia should, in the near term, concentrate on the ground-station equipment sector.
3. The major market thrust of Australian space activities should be in the remote-sensing sector, involving both hardware and software.
4. Research institutions and educational establishments should arrange to co-ordinate and consolidate their space capabilities in order to contribute effectively to development of Australian space science and technology.
5. The Government should take the leading role in facilitating the development of Australian space science and technology capabilities through the 1980's.
6. Australia should actively pursue the possibility of international collaboration in space and, in particular, of joint space initiatives with countries in the East Asian region.
7. A major component of the national space programme should be government-funded R&D contracts placed within Australian industry.
8. The first phase of the national space programme should have the objective of achieving in industry the capability to participate in complex spacecraft either as a subcontractor or with prime-contractor responsibility for a major system.
9. The space segment of the national space programme should be directed towards development of Earth resources spacecraft equipment suitable for inclusion in other nations' spacecraft or at some future time in spacecraft of Australian origin.
10. Australia should build on its expertise in reception, image processing and analysis of remote sensing data with a view to developing significant exports of hardware, software and ground receiving equipment; and becoming a regional centre for provision of processed data and images, and for training in remote-sensing techniques.
11. The Government should ensure a continuing Australian capability to receive the latest types of Earth observation satellite data and, in particular, should allocate funds at the earliest opportunity to upgrading the Australian Landsat station
12. Space science should be a continuing component of the annual budget for the national space programme.
13. Australia should participate in international space science and applications programmes relevant to Australia's requirements as a means of being involved in state-of-the-art developments.
14. The Government should accept a commitment over the next five years of up to A$100m to finance participation in a number of space projects in which Australia would have a significant design and construction responsibility, and associated basic research, general administrative costs and appropriate support facilities.
15. An independent Statutory Authority, with its own board of Management, should be created to:
    - advise the Government on space R&D policies and priorities;
    - co-ordinate and manage the national space programme;
    - liaise with research institutions, user groups, government departments and other agencies to establish long-term developmental requirements;
    - formulate and implement a co-ordinated and cohesive series of space projects in accordance with the national space policy;
    - place government-funded contracts in industry, research establishments and centres of higher education; and interface with the major overseas space organisations.
16. The national space programme should be reviewed at the end of the fourth year of operation.

The 194 page report is divided into chapters that provide justifications for the above recommendations. More than half of the volume is devoted to appendices with titles such as:

Overseas Space Activities
Current Australian involvement in Space Activities
Future Australian Operational requirements for Space Technology
Review of Australian Industrial Structure and Capabilities in Space-related Industries
Evaluation Methods for Large-Scale R&D programmes
Alternative Organizations Considered.

The next milestone will be dependent on the Australian government and parliament. As the Working Party pointed out, Australia has the technological and industrial potential. It can afford an effective programme with a total expenditure of A$100 million over the first five years leading to perhaps an annual expenditure of some A$60 million. There was one question identified as beyond the Working Party's terms of reference: 'Does Australia have the intellectual capacity to accept that this must be a national effort, all Australians making a contribution?' The politicians are obliged to answer this most fundamental concern.

An announcement on the establishment of an 'Australian Space Technology and Research Authority (ASTRA)' can be expected within the next six months if the Working Party recommendations for a July 1986 hand-over are accepted.

J. SVED
Stevenage, Herts

Soviet Space Station Designs?

Sir, We do not know the extent of knowledge gained from the Soviet Salyut programme but it is clear that the increasingly long periods of time spent in space have culminated in a new (238 day) record for Salyut 7, thus paving the way for yet further extensions to a year or more. Even if this is not possible with Salyut 7, it might be done with Salyut 8 when that is orbited, possibly around 1986-88. By that time the Soviets may have also achieved other goals e.g. orbiting a large Saturn type booster or a manned shuttle.

These underline a long-considered Soviet intent to carry out a full manned space programme *viz* not only to *put* men in space but *keep* them there, i.e. to set up a *permanent* station. This intent has been frequently reported in the West and, over a long period, has shown no signs of deviation.

If we add the possible development of a Nerva-type nuclear space propulsion unit, the situation would then exist that the USSR will not only have a large orbiting manned Space Station but will be able to accomplish a two man fly past of Mars by 1990 or 1992, with the nuclear motor required to clear the longer flight distances pertaining at those dates.

This would amount both to technical and political victories that would be hard for Western powers to match. The US Space Station would appear relatively mundane in comparison.

Thinking over such points underlines reasons why the UK should press for a full-scale manned orbital station, pertinent factors emerging are:

1. Until such a station is built, we cannot establish its uses nor explore its future potential, though it will clearly provide a stepping stone to many new experiments and to manned flight to the nearer planets.
2. Even if the USA and Europe do not embark on such a programme the USSR seems set on such a course. Salyut 8 could easily be a logical step in this. If large enough, it is likely that the USSR will invite other Communist country cosmonauts to take part in long term space experiments - longer in duration than are possible with the Shuttle.

In retrospect, it seems a shame that both the Skylab and the Nerva and Little Nerva nuclear programmes were abandoned just as they were showing signs of success.

If may be that the West is already a long way behind in the Space Station race. Participation by Europe as a whole and particularly by the UK would provide an extremely valuable boost.

A.T. LAWTON

Where is Everyone?

Sir, Articles in the *JBIS* and *Spaceflight* over the past few years have frequently raised the question: 'If there is intelligent life out there, where are they?' Many possible answers have been presented. Most of these, including some contributed by myself, have attempted to explore a possible motivation of alien life either in traversing space or sending messages: I exclude those articles that beg the question by 'proving' that there is no extraterrestrial life. I have in the past pointed out the dangerous fallacy in assuming that aliens will have motivations similar to our own. Reflecting on this, I feel that we might have missed an opportunity in failing to analyse our *own* motivation in wanting to explore space, so I was pleased to note in recent issues of *JBIS* contributions by sociologists and members of related sciences to this question.

The reason for this letter is to encourage us to examine ourselves and our own motivations, on the assumption that they may represent typical reactions of an intelligent species when faced with the prospect of interstellar flight or communication. What drives us and why are we interested? Conversely, what is standing in the way of our immediately starting work on development of probes with interstellar capability? If we can come up with at least partial answers to these questions, we may begin to understand the position of at least that part of the assumed interstellar community who are most like ourselves.

Such an examination might lead us to some hard facts that I suspect would not be pleasing to the majority of humanity; perhaps this is why this subject is so undeveloped. We may not be in a position to develop Isaac Asimov's 'Psychohistory' but we certainly have the statistical and logical tools to derive a few empirical rules about human behaviour! Perhaps this has already been done and I am not aware of it. If so, let's hear from some of the experts!

Some of the items might lead us to a better understanding relative to the inventive process, but it should also include references to those much-berated individuals who take an invention or process and drive it through political systems, laissez-faire and all forms of opposition to make it a practical reality. What is the cause of this drive and how can it be nurtured? Conversely, what is it that makes most of us instinctively feel that a new idea 'won't work,' or actively oppose it? What makes a bureaucrat tick and what distinguishes a good one from a bad one?

Many of us who work in the scientific field realise that, in order to get something done, simply having an idea that will work is a very small part of the whole picture. We have to be able to present it favourably, enlist the aid of bureaucrats, politicians and entrepreneurs with access to money, and drive it through all sorts of institutional obstacles before we even get the chance to prove that the idea is a good one. Is this a particularly human system or does it exist elsewhere?

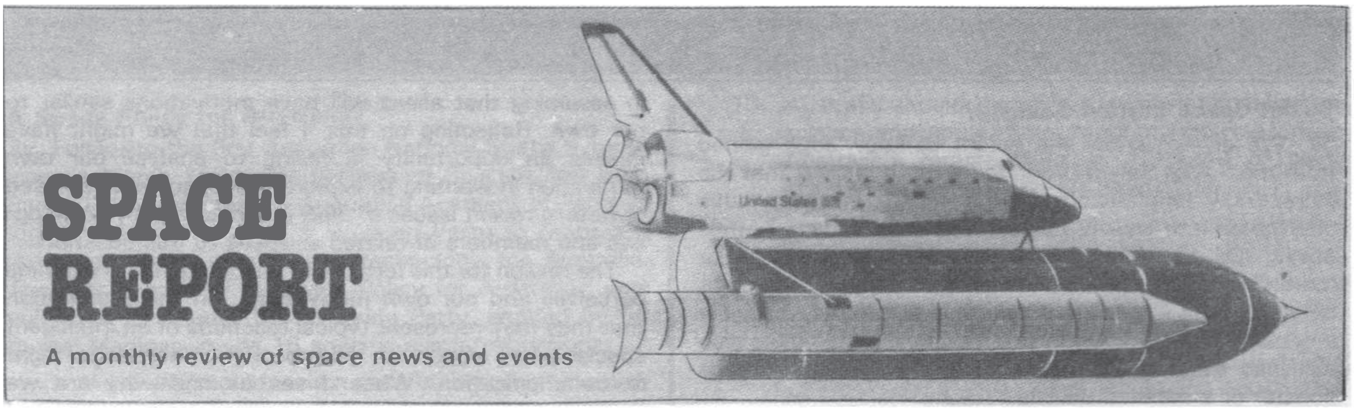
Knowing the answers would have two benefits. It would allow us to assess more accurately how many civilizations there are in our Galaxy who are actively looking for contact; and it would provide proponents of space flight with a set of rules for most rapidly advancing human endeavours in the direction of active interstellar exploration.

Most advances, I've heard it said, are achieved by less than 10% of the population, the remainder being 'sheep,' content to follow. I've seen nothing to disprove this notion and much in its support.

What makes us want to explore space anyway and how do we best go about getting it done?

DR. PETER MOLTON
Washington, USA

The Editor is always interested in receiving items of correspondence, notes, comments, or similar material for possible publication. Items submitted must be kept brief, owing to the limitations of space in our magazine. The Editor reserves the right to shorten or otherwise adapt material to fit, for this reason.



COMMUNICATIONS

INMARSAT TAKES TO THE AIR

Trials of a satellite communications system for aircraft—which may eventually lead to passenger telephone services—could begin later this year.

Inmarsat, the organisation which provides communication facilities for maritime and offshore applications, has announced significant steps in the new venture.

It has offered free capacity in its geostationary satellite system to the International Civil Aviation Organisation for tests and demonstrations of possible aeronautical satellite communications services and equipment.

Changes have been made to the international agreements under which Inmarsat operates to enable it to provide aeronautical services alongside those already used by the maritime and offshore industries.

Inmarsat will use trials to assess various aeronautical satellite concepts before committing a future satellite system.

An "initial system description" has already been made available to key organisations in the aeronautical community to support the discussions and for comments.

The document describes a possible aeronautical satellite communications system, providing both voice and data communications and using general purpose communications channels between aircraft and ground. The aeronautical community would be able to allocate different priorities for, and thus accord different treatment to, various types of messages ensuring urgent treatment of high priority messages.

During 1986 Inmarsat expects to have a number of prototype voice and data aeronautical satellite communications terminals available to interested airlines in a cooperative pre-operational trials programme to prove the system concepts and develop new applications, in particular passenger telephone and airline operational communications.

MEXICO SATELLITE AID

The chaos following Mexico City's devastating earthquake last September could have been far worse without the services of a communications satellite developed 18 years ago. NASA's ATS 3, located at 105° W longitude, through its control centre at Malabar in Florida, provided critical communications support for the international rescue and relief efforts of the American Red Cross and the Pan American World Health Organization.

The voice communications link with the outside world was crucial since the earthquake disrupted all other forms of communications in Mexico City. The capital would have been cut off but for the communications capability of ATS 3.

In a direct radio communication from Mexico City, George Manno, director of media relations for the Red Cross, said at the time: "the ATS 3 satellite is providing us with the most critical communications link to the rest of the world. We rely primarily on the ATS as our main communications vehicle." According to Dr. Claude DeVille, of the Pan American World Health Organization: "the ATS 3 satellite is extremely useful in any emergency situation such as the disaster that took place in Mexico."

COMMUNICATIONS TRENDS

Satellites will come increasingly into the orbit of Third World countries by the end of this decade, as more than 300 small Earth stations will be built in a $3,500 million spree to equip underdeveloped Asian, African and Latin American states with modern telecommunications.

Advances in satellite technology such as frequency re-use, on-board switching, special antennae to shape transmission beams and higher power levels have promoted the use of smaller and cheaper Earth stations, which is boosting the satellite market to a "distinct improvement on growth rates in previous payloads" by making hook-ups affordable to states of limited resources. A second factor is the widening practice of satellite system operators to lease transponder capacity to these nations.

Spending on satellite communications by the lesser-developed countries worldwide will reach almost $3,500 million in aggregate between 1985 and 1990, on average a real growth of nine per cent a year in the market. In constant 1984 dollars, the annual market will rise from $566 million in 1985 to a peak of $664 million in 1986, with a decline after the 1986-88 period to $545 million by 1990.

PROBING A THUNDERSTORM

A coordinated series of rocketborne experiments was conducted from NASA's Wallops Flight Facility on 9 September 1985 to study the effects of lightning in the Earth's troposphere. The simultaneous measurements were made from three rocket payloads in the air at different altitudes. Coordinated measurements were also made from a series of ground-based instruments designed to detect the location and characteristics of lightning.

A meteorological data sonde on a small rocket was also launched after the three-rocket series to determine the meteorological characteristics in the upper atmosphere near the time of the other measurements.

The three sounding rockets were launched over a period of about two minutes. A single-stage Orion was followed 70 seconds later by a two-stage Taurus-Orion, with a Nike-Orion after a further 57 seconds.

NEW 'SPACEHAB' MODULES

There is currently a backlog of several hundred funded NASA experiments that cannot fly aboard the Shuttle because of the lack of middeck locker space. This backlog is nearly doubling each year.

As the Space Station programme moves into hardware development and construction during phase C/D, which is scheduled to begin in 1987, NASA's Office of Space Station will require on-orbit testbeds in which to test automated systems, such as liquid transfer under micro-gravity conditions.

Now, the Spacehab company will build a module to fit in the Shuttle cargo bay just behind the crew cabin, accessed *via* the airlock, for astronauts to carry out and monitor many more experiments than is presently possible.

The modules will increase the pressurised living and working space on Orbiters by approximately 28 m^3, almost doubling existing pressurised volume of the crew compartment. Spacehab modules may be configured to contain as many as 100 standard middeck lockers and still provide an additional 20 m^3 of pressurised living and working space. The basic version will rely on payload bay power sources, share environmental control/life support resources with the middeck, and have passive thermal control. The first configuration will provide middeck augmentation for storage and experiments and astronaut sleep stations. Advanced versions will contain major subsystems and complex utilities, fluid loops, hard vacuum access, life support and power augmentation and active thermal control capabilities. Advanced module versions will be designed as Space Station testbeds and for use in Space Station construction, logistics and operations support.

Spacehab Incorporated will provide users with comprehensive payload services that include module volume lease, module/Orbiter integration (for full-module users), payload integration and payload mission support.

Costs for individual active and passive middeck locker accommodations, cost to lease dedicated Spacehab modules and the costs for specific Spacehab payload services will be determined during the Phase-B study, which will be completed during the first quarter of 1986.

Spacehab estimates that the cost of leasing dedicated basic modules will be about $5 million per flight. The cost of leasing the space of individual lockers for middeck type experiments will be a small fraction of the cost of leasing a dedicated module.

The plan is to have the first of the three modules ready for flight before the end of 1987, with five missions a year being possible by 1990.

HALLEY'S COMET MISSION

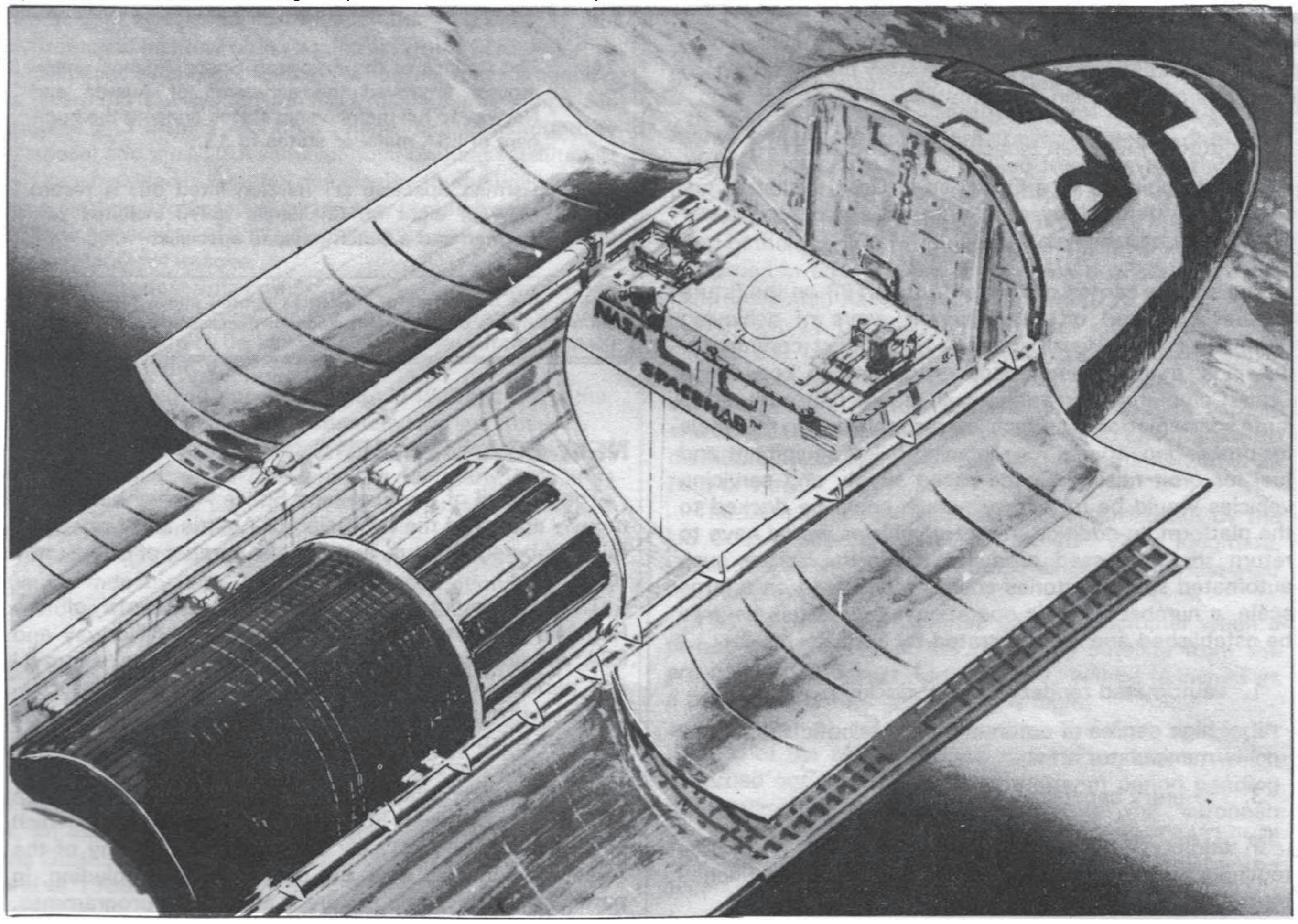
Astronomers Samuel Durance and Ronald Parise have been named as payload specialists to fly on Shuttle mission 61E in March.

Their objective will be to study Halley's comet and other celestial objects using three ultraviolet astronomical telescopes and a visible light, wide field camera.

The launch, using Columbia, is scheduled for 6 March and the seven member crew will be in orbit for eight days.

Durance is a research scientist at Johns Hopkins University, USA, and Parise is manager of advanced astronomy programs for the Computer Sciences Corporation, USA.

Spacehab will nestle in the cargo bay attached to the airlock by a short tunnel. *Spacehab Incorporated*



OTHER NEWS

SOVIET SPACE AGENCY

A civilian Soviet space agency has been formed by the USSR to act as a counterpart to the American NASA and other national space agencies.

Called Glavkosmos — an acronym for the Main Administration for the Creation and Use of Space Technology for the Economy and Scientific Research — its primary function will be to manage Soviet space science, space applications and co-operative international space ventures.

WATER ON MARS

Ice, snow, flowing rivers and vast lakes could have played a major role in shaping the ancient Martian surface and climate, a panel of scientists reported in early October. According to these new ideas, a thick layer of snow might have girdled the Martian equator in the planet's early years. Melted water running from beneath this snowpack could have carved out 'rivers,' the extensive winding channels imaged originally by Mariner 9.

In addition, huge ice-covered lakes might have formed in canyons near the equator early in the planet's history. Primordial Mars might have been warm enough to support flowing rivers and lakes on its surface.

ESA'S LONG TERM PROGRAMME

To prepare for the major decisions needed for European space transportation elements of the 1990's, ESA Member States have entrusted ESA with a Long Term Preparatory Programme (LTPP). Within this, a number of industrial studies are being made to identify projected STS user requirements, performing preliminary concept definitions of candidate STS elements and providing preliminary cost estimates. This preparatory programme concentrates on two main elements:

1. future European launchers beyond Ariane 4,
2. the build-up of a European In-Orbit Infrastructure (IOI) that will eventually permit Europe to master new capabilities.

The studies carried out so far in the LTPP on the future IOI have centred on the different ways of achieving European independent capability to conduct commercial missions; in particular, space processing in Low Earth Orbit. Complete automation would require fully automated large space platforms, which are resupplied with materials for processing, spares for replacing failed equipment and fuel for orbit raising. Space-based supply and servicing vehicles would be necessary, which could be docked to the platform. In addition, re-entry vehicles would have to return the processed products to Earth. Before such automated space factories could be operated on a large scale, a number of basic operational capabilities have to be established and demonstrated by Europe:

1. automated rendezvous and docking,
2. high degree of automation and robotic support by manipulator arms,
3. re-entry capability.

In addition, periodic manned intervention would be required, performed by the crew of a spaceplane launched by the future European launcher.

MILESTONES

September 1985

21 Hughes withdrew the Leasat 5 communications satellite from the Shuttle 61C manifest in December, pending further investigations into the Leasat 3 and 4 failures.

October 1985

2 Cosmos 1686 docks with Salyut 7. It is described as a star module, similar to Cosmos 1267 and 1443.

3 Military Space Shuttle mission 51J, using the new orbiter Atlantis, established a Shuttle high-altitude record of 320 miles (515 km) shortly after launch from Kennedy Space Center.

8 The tenth Navstar global positioning system navigation satellite is orbited by an Atlas E. Future launching will be made with the Shuttle and PAM DII upper stage.

15 Japan scheduled the first launch of its large H-2 vehicle for 1992. Development costs, including the first flight, total $800 M.

16 Shuttle orbiter Challenger is rolled out to the pad for the Spacelab D1 mission.

17 ESA's first pre-operational meteorological satellite, Meteosat F1, launched in November 1977, finally ran out of hydrazine fuel and drifted away from its position in geo-stationary orbit. It had originally been designed for a three year life.

23 NASA agreed with the Californian-based Scott Science and Technology company (headed by Gemini/Apollo astronaut David Scott) to provide assistance for a new Shuttle upper stage, the Satellite Transfer Vehicle. Most of the development work is being carried out by British Aerospace.

24 The Council of the European Space Agency unanimously approved the accession of Austria and Norway to full membership status bringing the numbers of ESA member states to 13.

30 German Spacelab D1 mission lifted off. A record crew of eight on Challenger (61A) included two German and a Dutch payload specialist.

Please note that some of the dates quoted above refer to the announcements of the events and not necessarily to the events themselves.

NEW ESA MEMBERS

The Council of the European Space Agency has unanimously approved the accession of Austria and Norway to full Membership status, bringing the number of ESA States to 13.

The agreement between the governments of the Republic of Austria and of the Kingdom of Norway and ESA will now be put forward for governmental approval and parliamentary ratification in the two countries concerned with the goal of achieving full Membership status for both Austria and Norway on 1 January 1987.

With this decision European cooperation in the space field will be strengthened. It comes after a period of close cooperation between ESA and the two countries which have, in fact, been closely associated with many of the Agency's activities over the past 20 years including, in particular, the Spacelab, Marecs and ERS-1 programmes.

HERMES COMPETITORS JOIN FORCES

France's two main aerospace companies — Aerospatiale and Dassault-Breguet — will jointly develop the country's Hermes manned mini-shuttle.

In a dual contract award Aerospatiale has been given the prime contractor role and Dassault-Breguet named delegate prime contractor with responsibility for aerodynamic design.

CNES, the French national space agency will retain authority as overall prime contractor and eventually hopes to share production with other countries agreeing to help finance the programme.

Ideally it would like Hermes adopted as a programme of the European Space Agency, within the framework of plans which also include the Ariane 5 launcher and the Columbus manned space station.

UK DATA SYSTEM FOR SWEDEN

A British firm is developing a meteorological satellite data processing system for the Swedish Meteorological and Hydrological Institute under a contract worth £225,000.

Software Sciences, based at Farnborough in Hampshire, is designing the system for the Prosat project which will process and display real-time image data transmitted by Meteosat and the NOAA series of polar orbiting satellites.

Once installed in Sweden one display station will be used for operational forecasting and one for research applications and the generation of a library of satellite scenes to assist in interpretation of images.

In another deal Software Sciences has been awarded the Project Definition Study for the Earth Resources Satellite (ERS) Data Centre to be located at the Royal Aircraft Establishment, Farnborough.

ERS 1 is due to be launched by ESA in 1989 and will gather data on the oceans and, experimentally, the land masses.

National centres, being established to collect and process the data, will provide data analysis for many industries including shipping, fishing, forestry and oil exploration, as well as scientific researach.

The UK ERS Data Centre is being funded by the Department of Industry and is expected to be operational by 1989, providing a service to industry and nations around the world.

ARIANESPACE LAUNCH CONTRACT

Arianespace and Inmarsat have signed a contract for the launch of the Inmarsat 2 F2 satellite in 1988.

Built by British Aerospace as prime contractor, it weighs around 1140 kg and will be put into orbit by an Ariane 4, an improved version of the European launcher, from the Guiana Space Center, Kourou, French Guiana, by the end of 1988.

Inmarsat, the 44 member country maritime satellite organisation, provides communication facilities for maritime, offshore and other mobile applications.

This order increases the total launch service contracts obtained by Arianespace to 35 satellites, out of which 23 remain to be launched for a value of about 6.5 billions French francs (or about $600 million dollars).

ARIANE READY TO GO

Europe's Ariane launcher should be back in operation in January with the launch of Ariane V16 from the Kourou site in French Guiana.

Missions were halted last year after the failure of an Ariane third stage on September 12 — the rocket was carrying a dual satellite payload both of which were destroyed.

Recommendations by an official inquiry have now been acted on and Arianespace — the commercial operator of Ariane — has announced the resumption of launch operations.

Mission V16, an Ariane 1 rocket carrying the French Earth observation satellite Spot and the first Swedish satellite, Viking, is scheduled for launch on January 11.

Ariane V17, due for launch on February 14, will be the first vehicle to use the new launch pad, ELA 2, at French Guiana. This version, an Ariane 3, will be carrying telecommunications satellites for the American GTE Spacenet Corporation and for Brazil.

Intelsat V is currently scheduled for launch during the second half of March 1986 on mission V18 and in addition Arianespace has plans for five further launches during the remainder of 1986.

MISSION ACCOMPLISHED

ESA's first pre-operational meteorological satellite Meteosat F1, launched in November 1977, has finally run out of hydrazine fuel and drifted away from its position in geostationary orbit to the extent that it is no longer "visible" from the Michelstadt (Federal Republic of Germany) ground station where the spacecraft's data was received, nor can it be controlled from the nearby European Space Operations Centre (ESOC).

Meteosat F1, designed for a three-year lifetime, has been gathering data from platforms which are either fixed or carried in balloons, on ships or on-board aircraft (the Data Collection Mission) over the last eight years.

As from 11 October the Meteosat mission has been carried out by Meteosat F2 (launched in June 1981) which, from its orbit at 0° longitude above the equator, will continue to produce pictures of the Earth's surface and cloud cover in the visible and infrared spectra and to distribute these images to user ground stations within its field of view.

The Data Collection Mission will be carried out by the US Goes-4 spacecraft, located at 43° West longitude, which has been "lent" to Europe since May of last year for this purpose.

This situation will continue until this summer when a re-furbished version of the prototype satellite from the pre-operational series, Meteosat P2, will be launched as a passenger on the first Ariane 4 flight.

According to present planning, the first spacecraft (MOP1) of the Meteosat Operational Programme, which is carried out by ESA during the interim period pending the ratification of the Convention of the European Meteorological Satellite Organisation (EUMETSAT), will be launched in summer 1987, to be followed by the second and third units respectively in 1988 and 1990.

TOWARDS NEPTUNE

By C.E. Kohlhase, R.V. Frampton and J.W. Gerschultz

A new chapter in the remarkable journey of Voyager 2 is about to be written during the forthcoming flyby of Uranus and in three years' time with an encounter of Neptune.

Introduction

The interplanetary exploration of Voyager 2 has already been the journey of a lifetime, stretching the imagination by an order of magnitude and providing valuable information about the two largest planets of the Solar System, Jupiter and Saturn.

Unlike its sister craft, Voyager 1, which is now heading towards the edge of the Solar System, Voyager 2 is on course for two further planetary encounters before it, too, follows a trajectory that will take it into the depths of space.

Voyager 2 will flyby Uranus in late January and, although its instruments were not optimised for encounters with planets beyond Saturn, impressive pictures and data on the system are expected.

Likewise, three years later, in 1989, the spacecraft will set another remarkable 'first' with an encounter of distant Neptune.

This article provides an insight into the Voyager 2 spacecraft and examines these exciting mission encounters.

Approaching Uranus

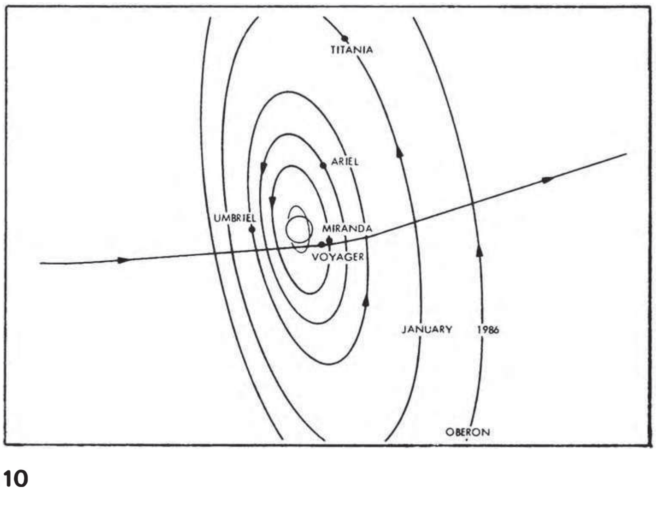
Relative to an observer on Uranus, the Voyager 2 spacecraft is approaching from approximately the same direction as the Sun appears in the sky, at a speed of about 53,000 km/hr.

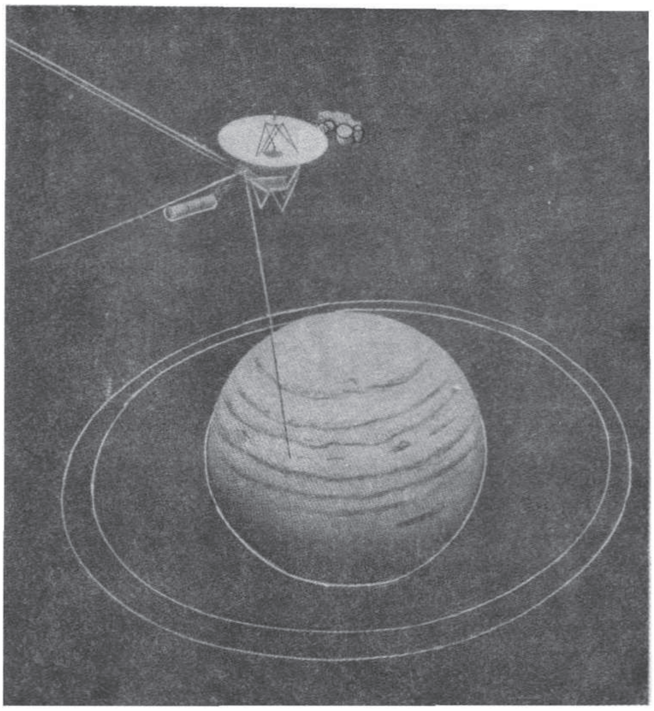
Uranus itself is orbiting the Sun at a mean distance of 19 Astronomical Units (1 AU = Earth-Sun distance) and, although travelling at some 24,000 km/hr, it still takes 84 years to complete just one orbit.

By the Uranus closest approach time of 18:00 GMT on 22 January 1986, Voyager 2 will have travelled more than 33 AU along its heliocentric path since leaving the Earth more than eight years ago.

Relative to an observer on the spacecraft, the Uranian system, with its five known satellites and nine known rings, resembles an enormous bulls-eye target almost 1,200,000 km across. This expanse is over three times the Earth-Moon distance.

Uranus is tilted on its axis, so that Voyager will approach it like an arrow nearing a target.





An artist's impression of Uranus encounter.

Uranus itself is truly a giant planet, with a diameter of 52,500 km, compared to the Earth's 12,700 km, representing a diametric ratio of four to one and a volumetric ratio of 69 times that of the Earth.

It is significant to note that the path of Voyager 2 must pass slightly within the orbit of Miranda, a Uranian moon, in order for Uranus to provide the proper gravitational deflection to continue on to Neptune. The exact encounter timing of 18:00 GMT was selected to optimise the geometry for Miranda coverage using image motion compensation.

At the time of closest approach radio signals will take 165 minutes to reach Earth, meaning that data transmitted at the time of closest encounter will not be seen until 20:45 GMT.

Fifty five minutes prior to the Uranus closest approach, Voyager will pass Miranda at a range of 29,000 km.

Spacecraft Instrumentation

The basic structure of the spacecraft, called the bus, is decagonal (ten sided) and the whole vehicle is designed to roll about its axis of symmetry, known as the z-axis, by firing hydrazine jets. Normally the spacecraft is aligned so that the z-axis points at the Earth.

Each of the ten sides of the bus (numbered clockwise 1-10) houses various electronic assemblies. For example, Bay One contains the radio transmitters.

To give the spacecraft full manoeuvrability, two further turn axes are incorporated into the basic design: x-axis (pitch) and y-axis (yaw).

Most spacecraft have small, steerable antenna dishes attached to the spacecraft bus but Voyager is different. It could be said that the spacecraft bus sits on the High Gain Antenna (HGA). The reason is that to establish acceptable communications between itself and the Earth over such vast distances the antenna must be very large, in this case 12 ft.

A high degree of accuracy is also required because the antenna focuses the radio energy into a concentrated, narrow beam. It operates at only half power after deviating by as little as 0.5 degrees off axis for the X-band frequency and 2.3 degrees for the S-band.

The X-band frequency, 8.4 GHz is used for the

transmission of science and engineering telemetry data at rates varying from 4.8 to 21.6 kilobits per second. The S-band channel is configured to contain only engineering data on the health and state of the spacecraft at the low rate of 40 bits per second.

Attitude Control

Voyager 2 is three-axis stabilised, controlled by an onboard computer known as the Attitude and Articulation Control Subsystem (AACS). It also controls movement of the scan platform.

Voyager has two ways of maintaining its attitude: by gyro control and by celestial control. Gyro control is used for special purposes and short periods (up to several hours at a time).

In celestial control mode, Voyager maintains its fixed attitude in space by viewing the Sun and a bright star. Should it drift from its proper orientation by more than a certain angle (known as the deadband), the AACS will issue commands to fire the tiny thrusters and bring it back on line.

Instruments used to track the Sun and star are the Sun Sensor, mounted on the HGA, and the Canopus Star Tracker, so named because Canopus is usually the preferred star in the sky because of its brightness.

On occasions during planetary encounter, when Canopus might be obscured by the spacecraft bus or the planet itself, an alternative in the opposite side of the sky is used.

To accomplish this, a Stellar Reference Change manoeuvre is carried out, thus meaning it is possible to maintain the spacecraft in the most favourable attitude at all times for photography and the gathering of data.

Scan Platform

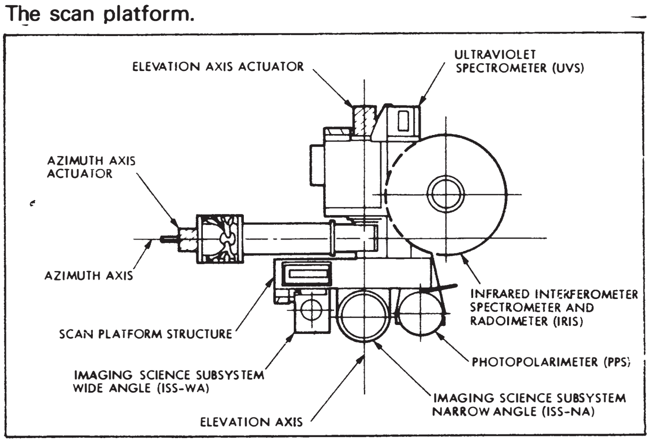
The scan platform is one of several appendages attached to the bus and it is here that most of the science instruments are located, including those that need to be pointed at the target body.

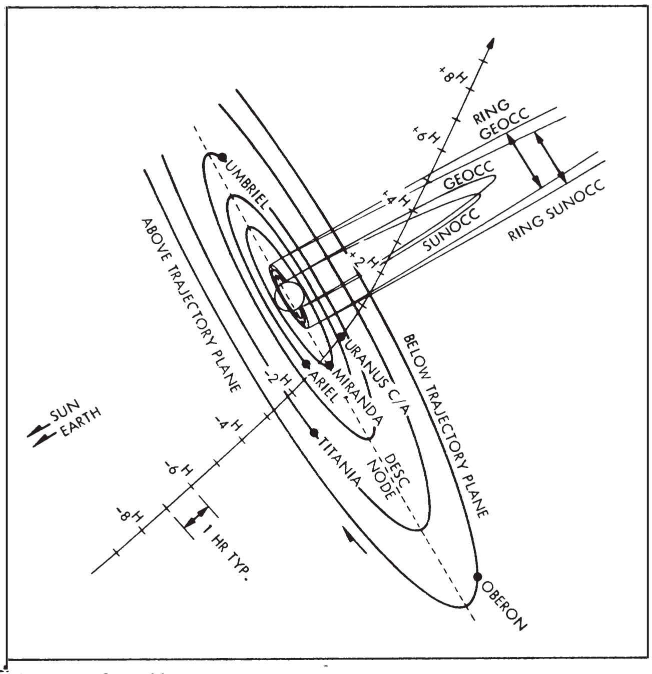
A long boom is used because of the advantage this gives the instruments in being able to look backwards at the planet or moon in question immediately after the closest encounter. The platform itself has motors and gears (called actuators) that slew it to point in various directions.

Almost 100 minutes after the Voyager 2 closest approach of Saturn in 1981, the azimuth motion of the scan platform unexpectedly halted, causing the loss of valuable science data from instruments that required pointing.

The seizure was due to the heavy use of the high-rate slews, causing a vital lubricant to migrate away from a tiny shaft-gear interface (spinning at 170 rpm), which then expanded slightly with the additional heat, finally

The scan platform.





Voyager 2 at Uranus.

leading to a seizure. Attempts to resume normal scan platform operation took two days.

As a result, the faster slews will not be used during the Uranus encounter and a contingency near-encounter sequence has been prepared just in case prior testing indicates the likelihood of the scan platform motion sticking again.

Spacecraft Power

Spacecraft electrical power is supplied by three Radioisotope Thermoelectric Generators (RTG) which are miniature nuclear power plants, converting about 7,000 watts of heat into some 400 watts of electricity. These lie along the RTG boom, away from the spacecraft bus and opposite the scan platform.

At launch the power output from the RTGs was 475 watts and this has decreased by about seven watts per year, due mainly to the half-life of the fissionable plutonium dioxide and degradation of the silicon-germanium thermocouples.

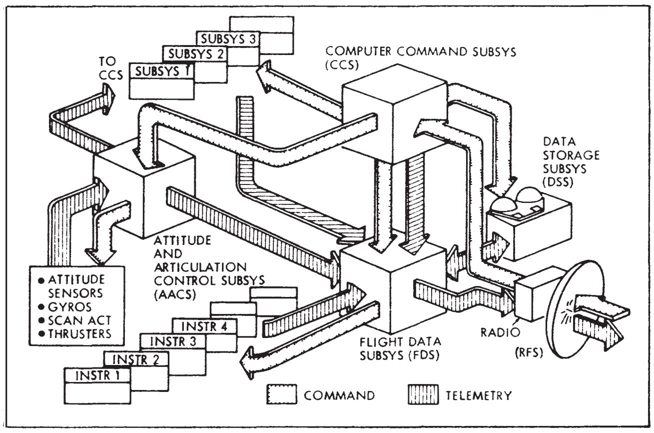
Power output for the previous two planetary encounters was 448 watts for Jupiter and 429 watts for Saturn, with an expected 398 watts for Uranus and projected 372 watts for Neptune.

The power requirements are constrained to be less than the RTG output and excess power is dissipated through the shunt regulator as heat. The difference between the available power and that used is known as the 'power margin' and since there is substantially less available for the Uranus encounter great care has been taken in planning a power management strategy.

For example, the S-band high power state cannot be used regularly and several other key power loads have to be turned off at some risk to use the S-band high-power state for the Earth Occultation Experiment.

On occasions when Voyager cannot immediately send science telemetry data to Earth, such as during a manoeuvre when the HGA is not pointed at Earth or during a time of occultation, the Digital Tape Recorder (DTR) is available to store the data for later playback to Earth.

However, data management is still a demanding task because it is important to get data played back as quickly as possible so the tape recorder can be filled again – and this must be balanced against the interface caused with science gathering.



Voyager's three computer subsystems.

The Computer Command Subsystem

The CCS, consisting of two identical computer processors, their software algorithms and some associated electronic hardware, is the central controller of the spacecraft. It has two main functions: to carry out instructions from the ground to operate the spacecraft, perform housekeeping functions and to gather science data; and to be alert for a problem with or malfunction of any of the subsystems and to respond to it.

The latter of these functions is carried out by a series of software routines called Failure Protection Algorithms (FPAs), which occupy approximately ten per cent of the CCS memory and make the spacecraft semi-autonomous and able to act quickly to protect itself.

Its other function, storing and processing commands from Earth, allows the spacecraft to act as an intelligent robot to carry out its science gathering functions in strict accordance with the carefully developed mission plan.

Science Instruments

There are 11 science instruments on Voyager 2 and all but four are located on the scan platform or its supporting boom. Of these four, the Magnetometer uses its own boom; the Planetary Radio Astronomy (PRA) experiment shares the 'rabbit ear' antennae with the Plasma Wave Subsystem (PWS) and the Radio Science Subsystem (RSS) uses the radio beams from the HGA.

Four instruments on the scan platform require accurate pointing: the Imaging Science Subsystem (ISS) wide and narrow-angle cameras, the Ultraviolet Spectrometer (IRIS) and the Photopolarimeter Subsystem (PPS).

The remaining three instruments on the scan platform boom, all fields and particles experiments, are the Cosmic Ray Subsystem (CRS), the Low Energy Charged Particle (LECP) experiment and the Plasma Subsystem (PLS).

All of these experiments, except for the RSS, send their observational data to the Flight Data Subsystem (FDS) for formatting into telemetry.

To Neptune and Beyond

The Voyager 2 encounter with Neptune during August 1989 will be the fourth and last swingby on this epic grand tour of the four giant outer planets. It will be a fitting occasion to celebrate the 12th anniversary of its launch.

To ensure that Voyager 2 will be able to complete its final planetary tour at Neptune, mission planning for the 'Voyager Neptune Interstellar Mission (VNIM)' started several months ago.

It was necessary to allocate critical spacecraft resources jointly for both the Uranus and Neptune encounters. Fortuitously, there appear to be adequate consumables to accomplish this task with little penalty extracted at either enounter, although some operational design margins (such as power) will be slim by earlier standards.

Other spacecraft performance limits that become critical are telecommunications (because of the greatly increased range to Earth) and imaging smear – because of the very long exposure time required with light levels 900 times fainter than those on Earth. Talking with the spacecraft will become more of an operational burden as well, because of the 8.2 hour two-way communication time.

Neptune, some 30 AU from the Sun, is truly at the outskirts of the Solar System, taking 165 years to complete a single orbit.

Despite being the fourth largest planet in the Solar System it is invisible to the naked eye and was discovered in 1846 based upon mathematical calculations of Uranus' orbit perturbations.

Triton, Neptune's largest moon and comparable in size to our own Moon, was discovered only days after the planet itself, but even with today's powerful telescopes little new information has been obtained, except for recent observations of partial rings just inside three Neptune radii from the planet centre.

Neptune should appear as a slightly oblate bluish-green ball with a diameter of 48,600 km, or nearly four times that of the Earth. Because of its largely gaseous nature, the mass is only 17 times that of Earth and its polar axis has only a moderate tilt of 28 degrees. It is estimated that the rotation rate of the outer atmosphere is about 18 hours.

Neptune and Triton Encounter Planning

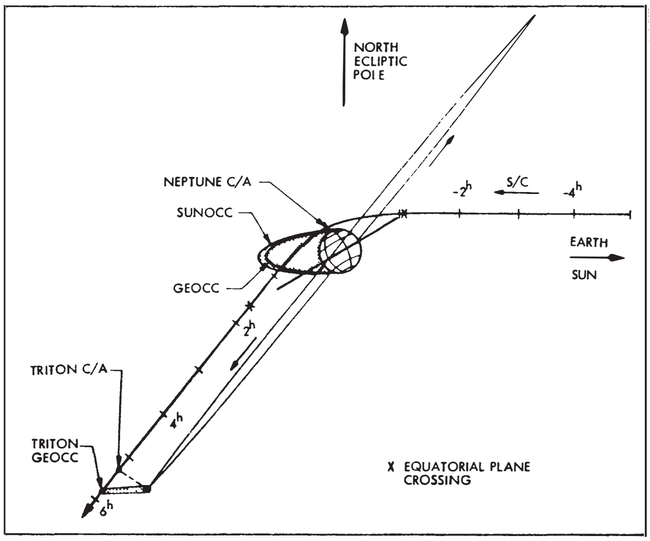
Without the availability of a gravity-assist corridor to continue to Pluto, a large number of trajectory options were studied in order to assess the relative science value of spacecraft observations made from each potential Neptune flyby mission.

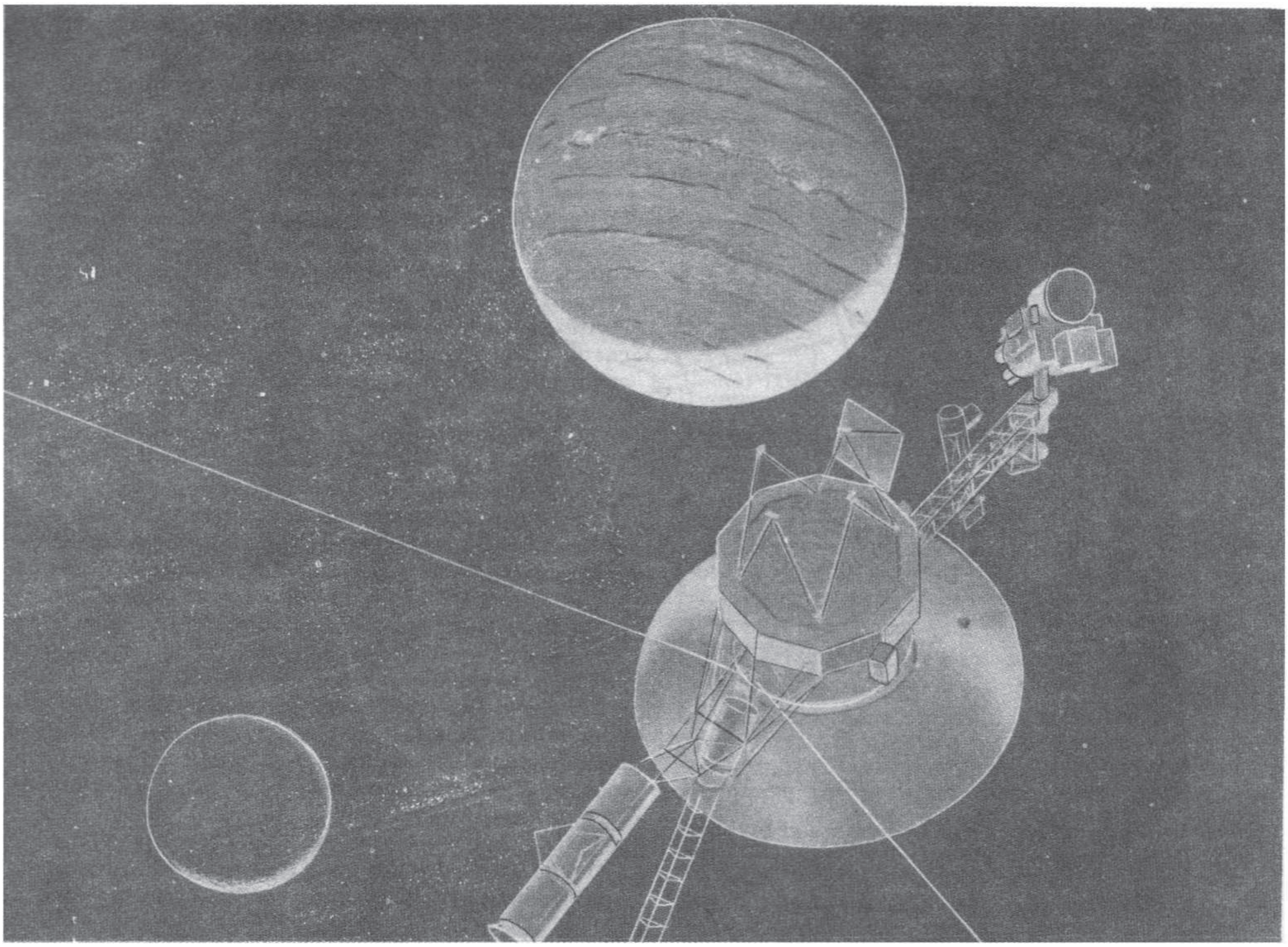
In the end, after months of debate, scientists agreed that a dual close encounter with both Neptune and Triton would be most desirable, especially since the satellite geometry would permit a reasonably good Earth occultation at Triton.

The resulting trajectory involves a special spacecraft velocity-change manoeuvre, just after the Uranus encounter, that will advance the arrival of Voyager 2 at Neptune in order to allow for proper phasing with Triton.

If all goes as planned, the spacecraft will skim over the north pole of Neptune a mere 1,300 km above the gaseous surface on 24 August 1989. The gravitational force of

Neptune encounter, August 1989.





An artist's impression of Neptune encounter.

Neptune will cause Voyager to veer sharply downwards, through both Earth and solar occultation regions by Neptune and out towards the orbit of Triton. About five hours and ten minutes after the Neptune closest approach Voyager 2 will pass within about 8,200 km of Triton's surface.

Although Triton may have a thin atmosphere of methane and nitrogen, the surface is expected to be visible to Voyager's cameras, allowing detection of surface features, including possible oceans of liquid nitrogen that have been suggested by some Earth-based observations.

Shortly after Triton closest approach, the spacecraft will pass behind the satellite to create the Earth occultation so highly valued by radio science investigators. This occulation will provide information about Triton's thin atmosphere as well as an accurate measurement of the large moon's diameter.

Post-Neptune Cruise Science

Following exploration of the Neptune system, the spacecraft will have completed an unprecedented series of encounters with the four giant outer planets and will have gathered valuable interplanetary information in addition.

At the conclusion of the VNIM on 31 December 1989, Voyager 1 will be at approximately 40 AU and 33 degrees north ecliptic latitude and Voyager 2 will be at approximately 31 AU and slightly south of the ecliptic plane. Both will continue to escape from the Solar System toward the solar apex and communications could be maintained as long as they continue to function. Logically, an extended mission should be conducted in anticipation of penetrating the boundary between the solar wind and the interstellar medium, allowing measurements to be made of the interstellar fields and particles unmodulated by the solar plasma.

It is expected that both Voyager 2, and its predecessor, Voyager 1, will remain alive for many years to come unless some unexpected failure were to occur.

Thanks to advance planning, there is no immediate concern about limited onboard resources, and the Voyagers (together with the Pioneers) will be the first spacecraft to continue their voyages into the outer reaches of the Solar System, to the heliopause and beyond.

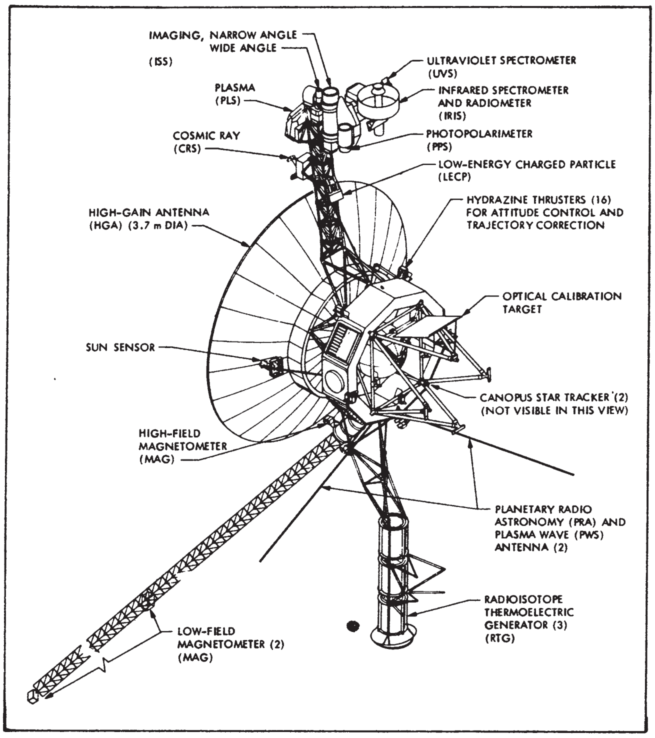
Obviously, this represents a unique opportunity to continue to extend the scientific charting of our Solar System as well as to gather new information about ultraviolet emissions from galactic sources.

With a little luck, one or perhaps even both of the Voyagers may be alive and well at the crossing of the heliopause boundary, where the interstellar medium restricts the outer flow of the solar wind and confines it within a magnetic bubble called the heliosphere.

This is a key scientific objective stated in the VNIM Project Plan. The exact location of this boundary is not known and it will most likely vary as a function of solar departure direction. However, it is believed to be located between 50 and 150 AU in the direction of travel for both Voyagers and Pioneer 11.

The Sun sensor might be the first resource limitation to occur at about 80 AU in the year 2001 for Voyager 1 and 2006 for Voyager 2, although there is an excellent chance it will continue to function well beyond 80 AU.

Thereafter, declining hydrazine reserves and/or minimal power requirements of 230 watts would be reached in about the year 2015 when the Voyager 1 and 2 spacecraft would be at heliocentric distances of 130 and 110 AU, respectively.



The Voyager spacecraft.

Typical scientific objectives to be addressed by interplanetary observations are:

1. Characterisation of the solar wind evolution with distance from the Sun (MAG, PLS, LECP, CRS).
2. Observation and characterisation of the Sun's magnetic field reversal (MAG, PLS, LECP, CRS).
3. Search for low-energy cosmic rays (CRS, LECP).
4. Characterisation of particle acceleration mechanisms in the interplanetary medium (MAG, PLS, LECP, PWS).
5. Search for evidence of interstellar hydrogen and helium and an interstellar wind (UVS, PLS).
6. Observation and characterisation of the heliospheric boundary where effects of the solar wind terminate (MAG, PLS, LECP, CRS, PWS).

In addition, interplanetary observations will be made (on a target-of-opportunity basis) to:

1. Search for radio emissions from the Sun in an environment well removed from planetary sources (PRA, PWS).
2. Search for and characterise galactic sources of extreme ultraviolet emissions (UVS).
3. Improve astrometric parallax measurements for selected stars using the substantially longer Voyager-Earth baselines (ISS).

To the Stars

The Solar System does not end at the orbit of Pluto, the ninth planet. Nor does it end at the heliopause boundary, where the solar wind can no longer continue to expand outward against the interstellar wind. It extends over a thousand times farther out where a swarm of small cometary nuclei are barely held in orbit by the Sun's feeble gravity (at that great distance).

The two Voyager robots will race past the orbit of Pluto by the end of this decade and barring random electronic failures they may even survive until several years after the turn of this century.

But even at speeds of 53,000 km/hr it will take nearly 20,000 years for the Voyagers to reach the comet swarm and by this time they will have travelled a distance of one light year, or nearly a quarter of the way to Proxima Centauri, the nearest star.

After the Voyagers have left the remote realm of comets they will make their way slowly to other star systems.

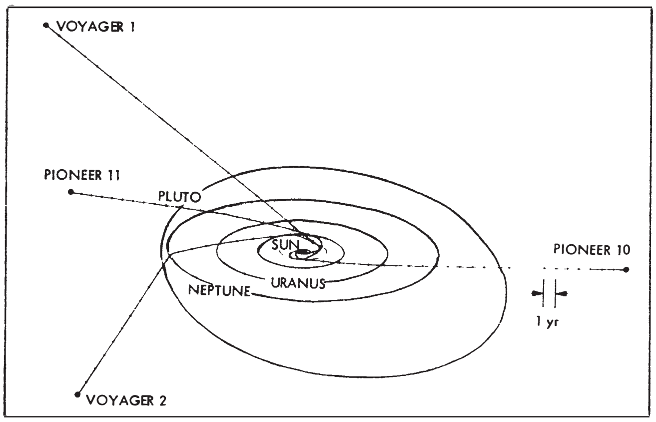
Affixed to each robot emissary from Earth is a gold-coated copper phonograph record designed by Carl Sagan and a small group of scientists and friends. The choice of a record was motivated by its ability to hold a large amount of information, and by the launching of the Voyagers during the 100th anniversary of the invention of the phonograph record by Thomas Edison.

Each record contains 118 photographs of our planet, ourselves and our civilisation; almost 90 minutes of the world's greatest music; an audio essay of special sounds; and greetings in almost 60 languages. An aluminium protective cover should ensure survival of the record for 100 million years against the occasional impacts from interplanetary and interstellar dust grains.

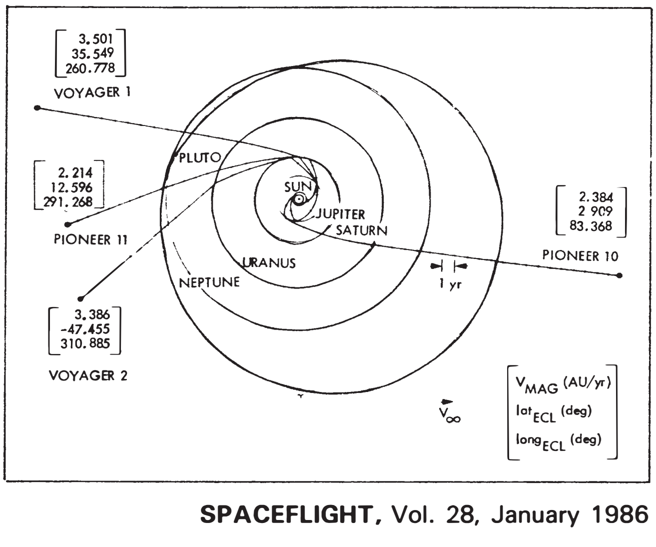
Though appealing to the human imagination, the possibility is extremely low that an extraterrestrial being will discover one of the Voyagers, rendezvous with it and play out the contents of the record. But it is still exciting to calculate the Voyager flight paths into the distant future, searching for close encounters with other star systems.

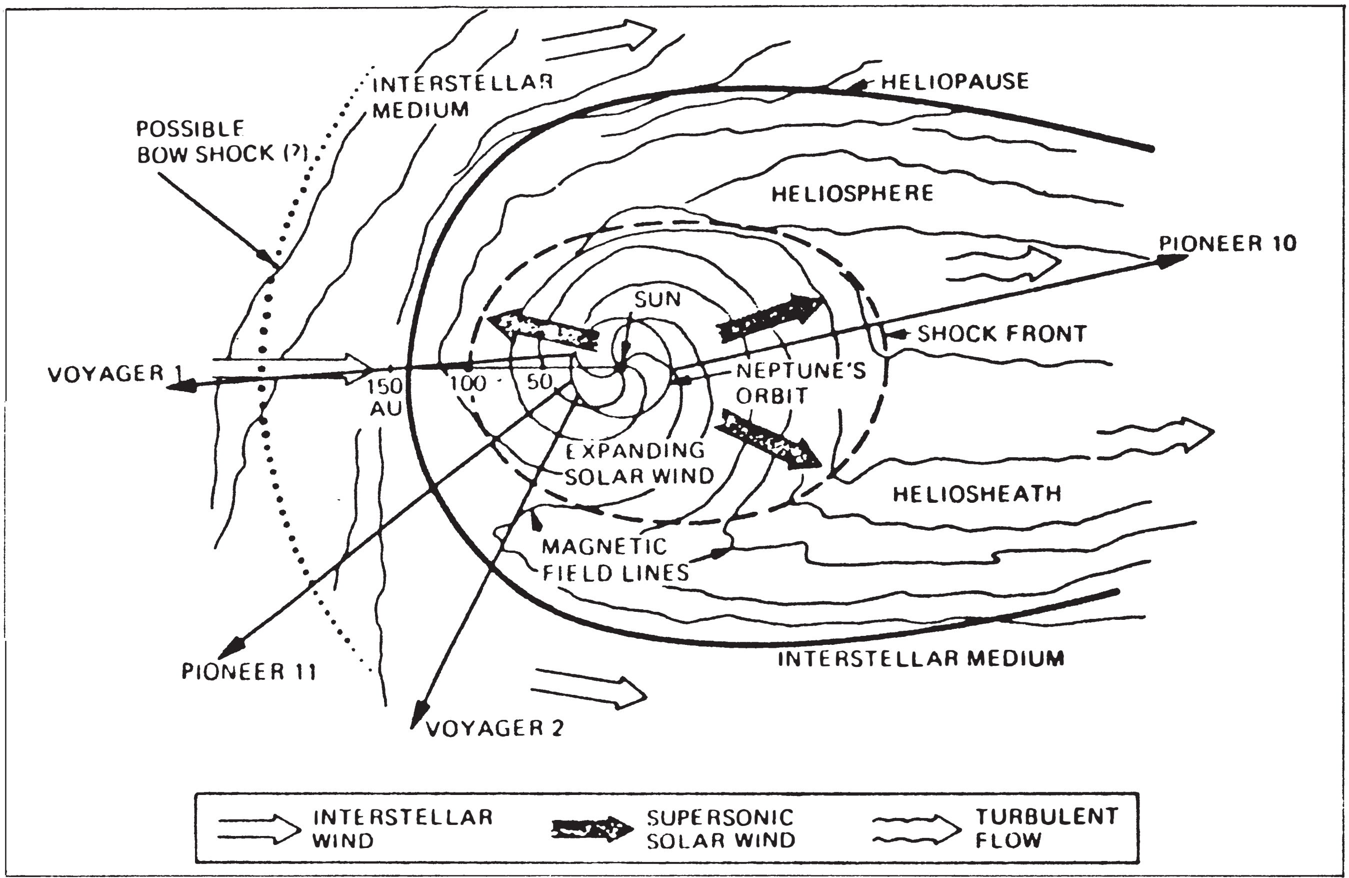
As the Voyager and Pioneer spacecraft travel out of the Solar System they will eventually attain their asymptotic

An ecliptic plane projection of the Voyager and Pioneer paths.



Gravity assist will deflect both Voyagers out of the ecliptic plane.





Departing the heliosphere.

departure directions, as seen on the sky of the current epoch.

Because the Voyager 2 flyby of Neptune will be over the north pole the departure trajectory will be deflected substantially south of the ecliptic and Earth equator, into the south polar area of the celestial sphere.

Plotting the departure trajectories against the background stars on the celestial sphere immediately suggests that, in the future (distant in human terms, close in geologic or astronomical terms), the trajectories of these four spacecraft may carry them past several other stars. Because of the slow speeds of the spacecraft (compared to the stellar distance scale) and the resulting long time intervals, and because of the space velocities of stars during this interval, it would not be expected that stars currently located in the direction of the outgoing asymptote would be the most likely candidate for stellar flybys. In order to determine if specific stellar flybys occur for these four spacecraft, it is necessary to propogate both the spacecraft positions and the star positions in order to search for future "close" encounters.

In about 40,000 years, Voyager 1 will pass within 1.6 light years of AC+79 3888, an aging star in the constellation of Camelopardus, at the boundary near Ursa Minor. Though only one third the size of our Sun, it could harbour planets. Also in 40,000 years, Voyager 2 will fly within 1.5 light years of Ross 248, a small star in the constellation of Andromeda. Radiation bursts from Ross 248 suggest unfavourable conditions for life-bearing planets.

Voyager 2 is not doomed to sail the cosmic seas in an eternal trek of absolute solitude. For, in 285,000 years, it will pass within 3.5 light years of Sirius, the brightest star other than the Sun in Earth's heavens. The dog star and its white dwarf pup, in the constellation of Canis Major, will appear as a bright beacon to the deceased robot craft.

It is evident that the Voyager spacecraft are travelling far too slowly for even a modest penetration of interstellar space within our lifetimes.

In the 21st century follow-on deep space missions will make use of new propulsion technologies, such as Nuclear Electric Propulsion, and these new spacecraft could develop Solar System exit velocities of 8-13 AU a year compared to Voyager 2's 3.4 AU/yr.

But even that is slow, so are we captive of an aging Sun that drifts about the Milky Way Galaxy at a mean distance of 1.7 x 10^{12} AU with a period of only 245 million years?

Only time will tell, but we must press forward and hope that a technological breakthrough can be achieved so that one day we can join a community of galactic civilisations.

Acknowledgements

The Voyager quest is a team effort and many people contributed to this work in a variety of ways. It is part of a larger effort originally published as JPL Document 2580, dated 15 August 1985. Regarding the original version, special thanks are in order for W. J. Kosmann, R. A. Neilson and S. H. Plagemann, who authored other sections of the document than those excerpted here; for L. F. Whyman, who provided invaluable typing and review assistance; for R. C. Dumas-Thibodeau, who prepared the artwork and layout design; to D. M. Wolff, who provided an exceptional review of the overall product, and to Clive Simpson who prepared this edited version.

The work described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

TV IN SPACE

By Michael Engle

The use of television systems in carrying out space work is becoming increasingly important. The author, an engineer at NASA's Johnson Space Center who helped to train astronauts to use the Shuttle's TV system, discusses their present value and what they might achieve in the Space Station and beyond.

Introduction

Now that the Shuttle is operational, its closed circuit television system is becoming increasingly important. Whereas, in the past, TV cameras were used mainly for public relations, people involved with the Shuttle are finding many and varied uses for the Orbiter's TV system. This trend, fuelled by advances in 'telepresence,' will become increasingly important in space, especially for Space Station operations.

The Orbiter TV System

The Orbiter closed circuit TV system consists of cameras, lens, onboard monitors, pan/tilt units, a video tape recorder and associated electronics. An Orbiter normally carries four payload bay cameras (two each on the fore and aft bulkheads), two cabin cameras, two monitors and a video tape recorder. If a remote manipulator arm is flown two more cameras are carried, on the wrist and elbow joints.

The TV camera consists of a silicon intensified target vidicon tube and a lens assembly. The image tube, combined with automatic light control circuitry, provides excellent low light level performance, with a dynamic range of about five million to one. The cameras can use any one of three lens versions:

- monochrome lens
- colour lens (a monochrome lens with a colour wheel)
- a wide angle lens, with a wide field of view and a colour wheel.

The crew can see only black and white on their monitors. The videotape recorder used by the astronauts carries a 30-minute cassette.

In training, crews are taught with a variety of simulators, using both mockups and computer-generated views. In addition, a 'Photo/TV Checklist' is carried on each flight to help the astronauts set up the TV system, achieving proper fields of view and collecting video data for payloads.

Operational Use

The Orbiter TV system was originally designed as a Class III system, i.e. it was not critical to mission safety or success. As the Shuttle became operational, however, it became increasingly important to mission success (i.e. Class II). An example is the repair of the Solar Max satellite on flight 41C in April 1984. Without the TV system, berthing and repairing the satellite would have been extremely difficult, if not impossible. The arm wrist camera proved invaluable when astronaut Terry Hart performed the complex 'rotating grapple' to capture the wobbling solar observatory.

Another example, following the failure of both Payload

Astronaut Bob Crippen works on the Shuttle during STS-7 in June 1983. Behind him is a TV camera. *NASA*

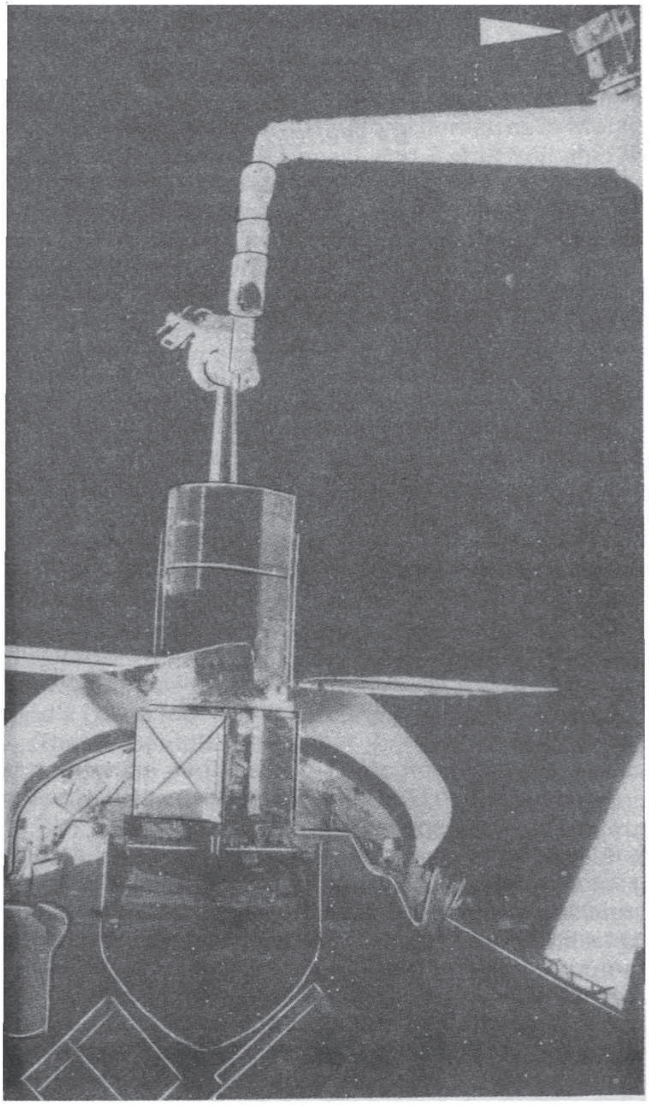
Assist Modules on flight 41B in February 1984, was the addition of an operational requirement to view the motor burn on all flights carrying these modules. Videotapes will then help engineers to analyse future performance.

As satellite servicing assumes a larger role in Shuttle operations, the role of TV will grow correspondingly. Real time visual data are essential for vehicle inspections, payload deployment and retrieval, extravehicular activity support and spacecraft repairs. Eventually, space servicing will become analogous to marine salvage operations where divers performing on-the-spot servicing are complemented by team-mates on the surface monitoring the work *via* television.

Payload Support

Shuttle users are beginning to realise the potential of using the Orbiter's TV system for data collection and operational support. An example is the experiment called 'Experimental Assembly of Space Structures (EVA)/ Assembly Concept for Erectable Space Structures,' better known as Ease/Access, which will use the television system to record spacewalking crewmembers manually assembling simple structures. Using the resultant video recordings to conduct a time and motion study, an accurate model of human productivity during EVA construction may be developed.

Another payload that relied heavily on the TV system



The repair of the Solar Max satellite in April 1984. The 'elbow' camera on the manipulator arm is arrowed. *NASA*

for data collection was OAST-1, an extendable, 32 m long solar array mounted in the cargo bay and carried on 41D in June 1984. The dynamic performance of the extended array, with visible targets, was recorded and monitored for later analysis.

On Spacelab 3 early this year, TV will be used to view and record auroral activity. 'Astro' is an ultraviolet astronomy payload that will observe Halley's comet in February 1986; TV will be used to help Astro point its instruments in the right direction.

In the future, the Orbiter's TV system will continue to play an active role in operations and payload support. Possible changes include using lighter, smaller cameras with better colour capability, higher resolution monitors and voice-operated controls. Such changes will also pave the way for the sophisticated TV monitoring and telepresence capabilities required for the Space Station.

Space Station TV Systems

Following President Reagan's directive in January 1984 to begin work on the Space Station, NASA is undertaking a myriad of studies. There is the potential to design a sophisticated and flexible Space Station TV system, benefiting from experience gained with the Shuttle.

Video systems will prove invaluable in conducting routine operations and maintaining the psychological health of the crew. The station will probably include several free-flyers, independent, co-orbiting platforms containing experiments or production facilities. These platforms will need to be monitored with the minimum of disturbance; the best way is *via* a closed circuit TV system. Space station performance and integrity must also be monitored visually, necessitating some sort of TV system. A dual transmit/receive and closed circuit TV system could provide crews with entertainment (films, games, etc), as well as allowing private conversations with family and friends on the ground (the latter has been a feature of Soviet Salyut missions).

An important function of the Space Station will be traffic control. It will not only monitor and control the free-flying platforms but will also serve as a staging post for payloads bound for different orbits. Like an airport control tower, the station will coordinate payload arrivals and departures, maintain separation and provide maintenance and refuelling services. It will require very sophisticated electronic ranging and monitoring instrumentation. Traffic control will probably be accomplished by both laser and radar, as well as visually. A visual capability, *via* both windows and TV monitors, will serve as a complementary method of traffic separation, as well as backup to the avionics.

Extravehicular activity will be an important part of Space Station operations. Initial construction of the station will involve extensive spacewalks and subsequent operational activities and will, routinely, depend on EVA. TV monitoring will be necessary to support such operations, both to monitor crewmembers' safety and to help them in their work.

In the long term, the visual monitoring of today will be replaced by telepresence, intimately involving the human operator in a robotic control system. Future teleoperator systems will meet and even exceed the capabilities of the human eye. In the not-too-distant future such technology will, as George von Tiesenhausen of NASA's Advanced Systems Office puts it, allow you to 'do things in space as if you were really there.' As this field develops, more and more EVA tasks will be performed by crewmembers inside the station *via* teleoperator devices. NASA believes that telepresence capabilities will equal human EVA abilities by the 1990's. Initially, stereo black and white televisions will be used on the teleoperators but these cannot match the capability of the human eye. Eventually, NASA hopes to have teleoperator cameras with both colour and wide fields of view - these require a far higher number of communication bands than are now available. Such camera systems will match and perhaps exceed the resolution of the human eye.

A Space Vision System, built by the Canadian National Research Council, flew on the Shuttle in late 1984 aboard mission 41G. It might prove to be the forerunner for Space Station TV monitoring systems. It uses either a natural or laser light beam, interfacing with an onboard computer, to provide depth perception when manoeuvring or grappling payloads with the Orbiter's manipulator arm. A Canadian payload specialist, Marc Garneau, monitored the TV image aboard the Orbiter. In the future, such computerised vision systems will be an important tool in building the Space Station and other large space structures.

There appears to be no insurmountable obstacles to building and operating a TV monitoring system for the Space Station. The environment does not pose a problem, as the station will not be exposed to excessive radiation (which could damage a camera's silicon tube) and thermal control can be achieved by using methods such as shading, thermal blankets and strip heaters. The greatest problem is providing camera cooling during long periods of continuous operation.

Space News and Commentary

From the US Capital

By Walter Froehlich

CATCHING UP WITH A COMET

Halley's comet has been seen on its periodic visits to the vicinity of the Earth for more than 2,000 years. But it has never had a more enthusiastic welcome than it is currently getting from NASA and other space organisations.

Records describing the comet have survived for each of its last 29 appearances at intervals of 75 or 76 years from 240 BC to 1910, except for the year 164 BC. During many of these appearances the comet was regarded an evil omen — a heavenly harbinger of doom — even though its travels near the Earth have been accompanied and followed by as many auspicious events as detrimental ones.

This time around, the comet's arrival is considered by many scientists to be a once-in-a-lifetime research opportunity, and they are going at it in a big way. Research equipment has vastly improved in the 75 years since the comet's last visit in 1910. For the first time it can now be inspected from above the obscuring atmosphere. Ground and aerial observations are being supplemented by an array of spectacular space missions:

- NASA is sending its sparkling new astronomical observatory "Astro-1" on its maiden flight aboard the Shuttle's cargo bay on March 6. During their seven days in orbit, the Shuttle crew will be assigned to use Astro-1's three ultraviolet telescopes and two wide-field cameras almost exclusively for observations of the comet.

- Earlier, on a January Shuttle mission, a "Spartan" experiment package containing automated research instruments is to be released into a free-flying orbit for 48 hours and then retrieved so that its recorded comet observations can be analysed upon return to Earth.

- NASA's Pioneer Venus Orbiter, which has been circling Venus since 1978, will swivel its ultraviolet spectrometer toward Halley's comet. The craft will be in a unique position on the opposite side of the Sun from Earth. From that unusual vantage point the craft will be able to examine the comet during its closest approach to the Sun. At that time the comet will not be be visible from the Earth because the Sun is obscuring it. The craft will observe gases and dust emanating from the comet.

- The US Solar Maximum Observatory, which made history in 1984 when it became the first disabled spacecraft restored to service by an in-flight repair crew aboard the Shuttle, will also turn its instruments towards Halley's comet. The craft's coronograph that had been designed particularly for its Sun studies will produce images of the comet and its spectrometer will examine the comet's nucleus.

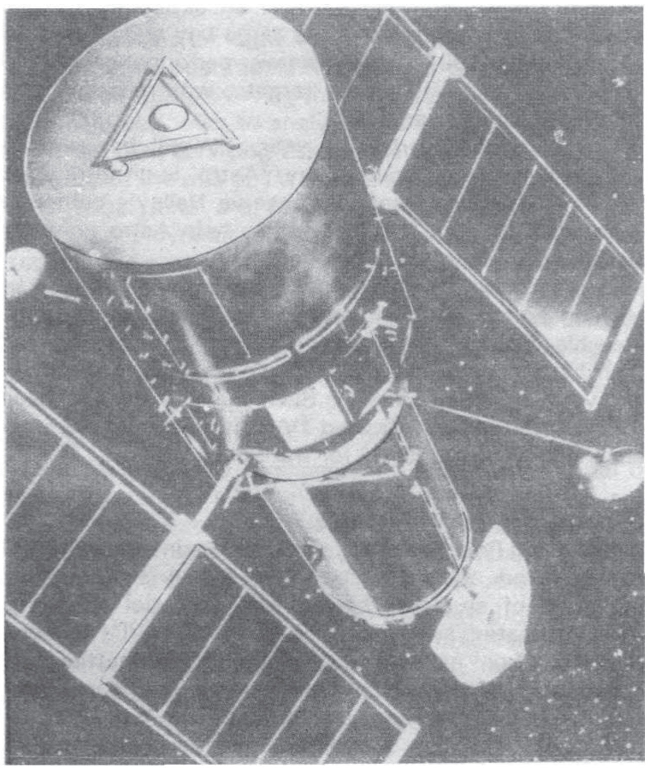
- The International Sun-Earth 3 Explorer (now renamed ICE, for International Cometary Explorer) which has been in a high-altitude orbit for solar wind monitoring since 1978 will make spectrographic analysis of Halley's components. That craft already made history in September 1985 after its course was altered and it became the first human-made object to come close to a comet.

The experience gained during that encounter is proving helpful to US Halley watchers as well as to the ground crews of spacecraft of other nations.

All of this extensive comet research comes, ironically, after NASA had been subjected to severe criticism within the United States for allegedly failing to take full advantage of the appearance of this most famous of all comets. The critics have been charging that NASA, for budgetary reasons, assigned only already existing research equipment rather than designing a new mission dedicated solely to Halley's comet explorations as some other countries are doing.

Thus, the European Space Agency launched its Giotto spacecraft on July 2, 1985, on a path which is to

The Hubble Space Telescope, due for launch during 1986.



take it, after course refinements, to within about 500 km of the comet's nucleus on March 13, 1986. Japan launched its first two interplanetary spacecraft — "Planet-A" and "Sakigake" — to look at the comet from distances of several million kilometres in March. And the Soviet Union Vega 1 and 2 craft will also fly within a few thousand kilometres of Halley's comet for observations early in March.

NASA is playing a vital part in these multi-national observations through its co-sponsorship with West Germany of the International Halley Watch (IHW).

The twin headquarters for the IHW, staffed by scientists from many countries, are located at NASA's Jet Propulsion Laboratory in Pasadena, California, and West Germany's University of Erlangen-Nurnberg.

A YEAR FOR SPACE SCIENCE

NASA's activities pertaining to Halley's comet are part of an array of projects which have motivated NASA to declare 1986 as "A Year for Space Science." NASA is arranging exhibits and other public education programmes which vividly show how space exploration continues to drastically expand humankind's vision into our cosmological neighbourhood.

These exhibits and other programmes also call attention to some of NASA's other major science activities planned for 1986:

- The January fly-by of Uranus by the US Voyager-2 spacecraft. It will be history's first close-up examination of that planet which is more than twice as distant from the Earth as any object ever examined in such detail.

- The launch of the first explorations, late in 1986, with the revolutionary Hubble Space Telescope which NASA Administrator James M. Beggs has called perhaps the most important scientific instrument ever flown, and which some scientists have hailed as "the scientific instrument of the century".

- The launch in May of the Galileo spacecraft on an 18-month journey to Jupiter where the craft will release a 1.5 m diameter entry probe that is to descend into and analyse the planet's atmosphere.

- A possible close-up inspection of the asteroid Amphitrite. No decision has yet been made on whether to undertake that historic mission by steering the Jupiter-bound Galileo spacecraft on a detour to the vicinity of that 200 km planetoid in the middle of the asteroid belt about two and a half times as far from the Sun as is the Earth. If the decision is made to divert Galileo on the side trip, the craft's arrival at Jupiter would be delayed by about three months.

Scientific exploration has always been a major objective of the US space programme and NASA's 1986 projects promise to become particularly productive. They encompass the experience and technological knowhow accumulated over more than a quarter of a century of operations in space.

As they extend humankind's view, these projects will undoubtedly add substantially to our knowledge about the solar system and the laws and workings of nature that govern everything within it and in the universe beyond.

News Bulletin

COSMONAUT ILLNESS FORCES EARLY RETURN

Cosmonauts onboard the Soviet Salyut 7 space station unexpectedly returned to Earth in late November after the commander, Vladimir Vasyutin, fell seriously ill.

This was the first time in the history of manned space activity that a mission has been curtailed by either the Soviets or the Americans for such a reason.

First news of the cutting short of the unfinished programme after 65 days came on November 21 when Tass announced that the three cosmonauts from Salyut 7 had returned safely to Earth in their Soyuz 14 craft.

Doctors were on the scene at touchdown in Kazakhstan, a Central Asian Soviet Republic, to examine the commander but no details of his illness were released.

A subsequent Tass statement said: "Vasyutin's condition is satisfactory. We cannot say any more than that as we have to make a thorough check-up. It is only clear now that, as we expected, he needs hospital treatment."

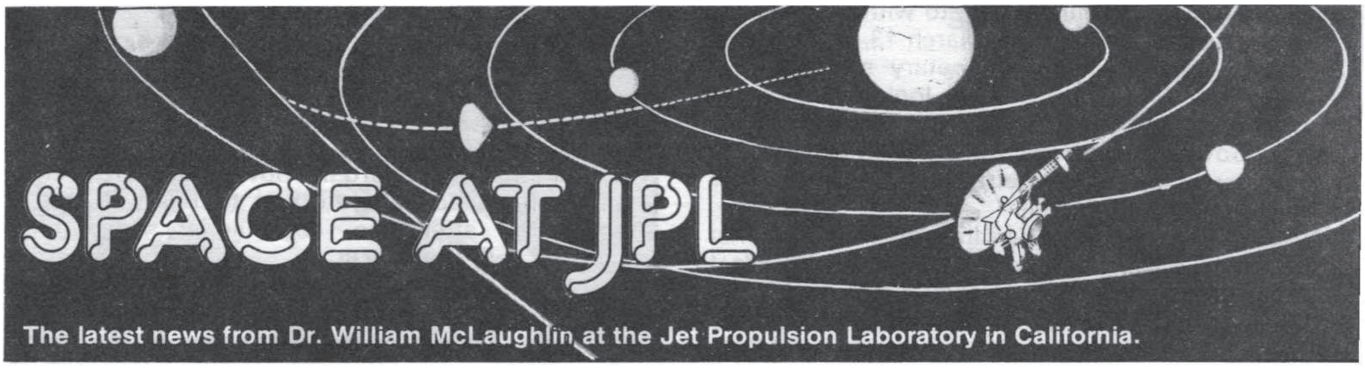
Vladimir Vasyutin

Vasyutin (33) went into space on September 17 with two other cosmonauts, Georgi Grechko (flight engineer) and Aleksandr Volkov (researcher-cosmonaut), carrying out a joint eight day mission with the cosmonauts already there, Dzhanibekov and Savinykh. Grechko and Dzhanibekov returned to Earth in Soyuz T-13 on September 25.

Since then the remaining three cosmonauts had been working on an extensive scientific programme which included taking pictures of six million square miles of Soviet territory for use by scientific and other bodies.

Vasyutin was assigned to the cosmonaut detachment in 1976 at the age of 24, completing test pilot school the following year. He was on his first space mission, although had previously been a member of training programmes on four back-up crews.

No immediate indication was given by the Soviet authorities about how long the commander had been ill before the decision to abort the mission was taken.



MARS AERONOMY ORBITER

In the July-August and December 1985 editions of 'Space at JPL,' two candidates for the second mission in the Planetary Observer series were examined: the Lunar Geoscience Observer (LGO) and the Near Earth Asteroid Rendezvous (NEAR). The first mission in the series is the already-approved Mars Observer project; this month a third candidate to follow that mission will be reviewed: the Mars Aeronomy Orbiter (MAO).

The dictionary defines aeronomy as a 'science that deals with the physics and chemistry of the upper atmosphere of planets.' Following the advent of radio in the late 19th century, Heaviside and Kennelly postulated in 1902 that transmissions were accomplished by the reflection of radio waves from a layer of charged particles in the upper atmosphere. These particles were detected in 1924 by the British physicist Sir Edward Appleton (1892-1965). The structure of this region of charged particles, the ionosphere, varies greatly with solar activity and has seasonal and daily patterns of fluctuations, as anyone who listens to radio can attest. The ionosphere extends from approximately 50 km to 1000 km above the Earth and can be divided into three distinct regions.

Research into the structure and dynamics of the Earth's upper atmosphere has been greatly facilitated by the use of sounding rockets and satellites. The first US satellite, Explorer 1, resulted in the discovery of the Van Allen belts, whose reservoirs of trapped protons and electrons gird our globe. The interaction of the solar wind with the Earth's magnetic field continues to be an active area of research.

Aeronomy investigations for the other planets are in their infancy. The Pioneer-Venus (1978) mission has begun that service for Venus. In the case of Mars, the emphasis to date by NASA has been on geology, biochemistry and properties of the neutral atmosphere.

The scientific goals for MAO are to characterise the magnetic field of Mars, the interaction of the planet with the solar wind and the structure and dynamics of the upper atmosphere. More specifically, daily and seasonal variations of the upper atmosphere are to be determined; the question of whether Mars has an intrinsic magnetic field is to be addressed; and the present escape ratio of hydrogen, oxygen and nitrogen from the atmosphere are to be measured. These last data would have important consequences for the study of the evolution of that atmosphere.

In order to accomplish these goals, three different experimental methods have been identified: (1) *in situ* measurements of atmospheric constituents, (2) optical remote sensing of the atmosphere, and (3) measurements of plasmas and electromagnetic fields. The first set of measurements can be done through the use of mass spectrometers, while the second set would require interferometers. Several instruments, including a magnetometer, electric field detector and solar wind plasma analyser, would implement the third item.

A possible launch date for MAO is September 1992, with a one-year flight time to Mars. Then, starting in the autumn of 1993, MAO would collect data for about one Martian year (approximately two Earth years).

The orbit of MAO about the planet would be highly eccentric so that the instruments could sample a wide range of atmospheric levels. It would also be highly inclined to the Martian equator to allow measurements to be taken at most latitudes. The period is planned to be greater than 20 hours. During this period data are gathered at three different rates. In the high regions of the orbit (that is, around 'apoareon'; the suffix is derived from 'Ares,' the Greek equivalent of the Roman Mars) data are collected at 512 bits per second and put on to the spacecraft's tape recorder. As the spacecraft draws closer to Mars, entering the ionosheath region, the data rate doubles to 1024 bits per second. Then, 15 minutes before periareon, the data rate doubles again to 2048 bits per second. At these rates, more than 80 million bits are generated each day and played back in a 4.5 hour daily downlink.

The mission could be accomplished with several spacecraft designs. The one that is selected, should MAO be chosen as the second Planetary Observer, would be influenced by the spacecraft for the Mars Observer. If that prior mission employs a dual-spin spacecraft, then MAO would probably follow suit. But if the Mars Observer is three-axis stabilised (does not spin), then MAO might go to a different design. A low-cost alternative would be to spin the entire spacecraft for stabilisation; fields and particles experiments thrive in this type of environment.

A fourth Planetary Observer candidate, in addition to MAO, LGO and NEAR, is the Comet Coma Sample Return. That mission will be reviewed in a later edition of this column.

KECK TELESCOPE GROUNDBREAKING

The Keck 10 m telescope, scheduled for completion in 1991, will be placed on top of a 4,150 m dormant volcano, Mauna Kea, in Hawaii. On 12 September 1985 ground was broken at the site in a ceremony attended by some 150 officials and guests. The Keck Telescope should be the largest in the world at the time of its completion (see the June 1985 edition of this column).

The telescope will be constructed from a $70 million grant from the W. M. Keck Foundation to Caltech (Caltech operates JPL for NASA). The California Association for Research in Astronomy (CARA) is a corporation that has been formed by Caltech and the University of California for the purpose of building and operating the Keck Telescope. The two institutions will share viewing time equally and also provide access for the University of Hawaii, from

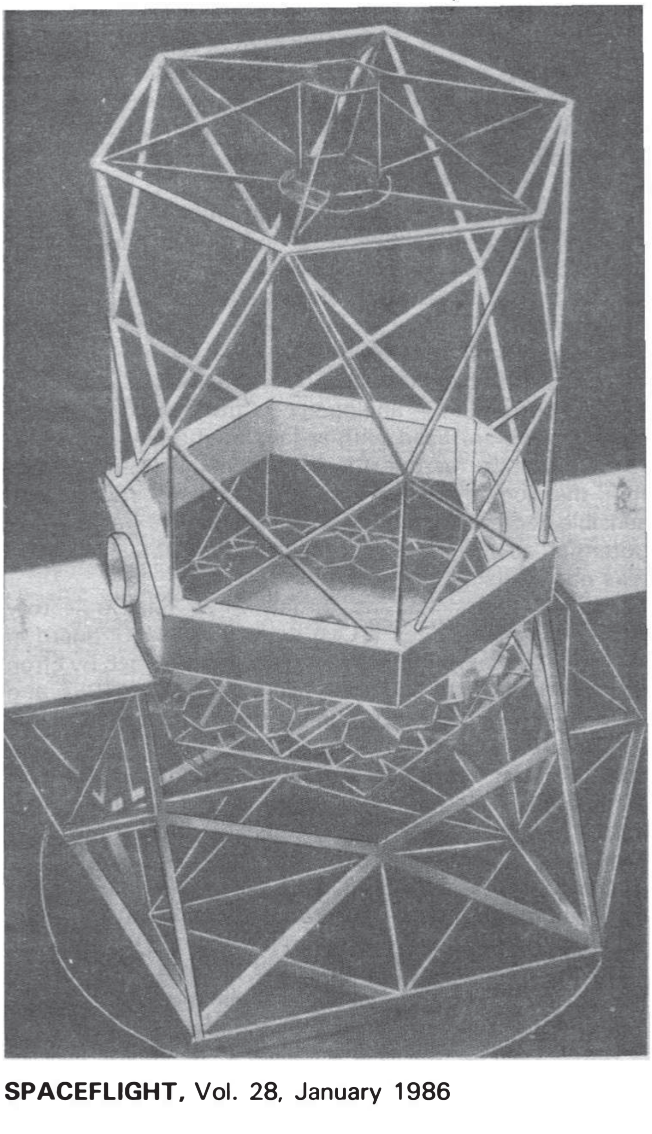
which the observatory land is being leased. The estimated $87 million in construction funding will be provided by Caltech, the bulk of this funding comes from the Keck grant, while the University of California will provide funds for instrumentation of the telescope and operation of the facility for 25 years.

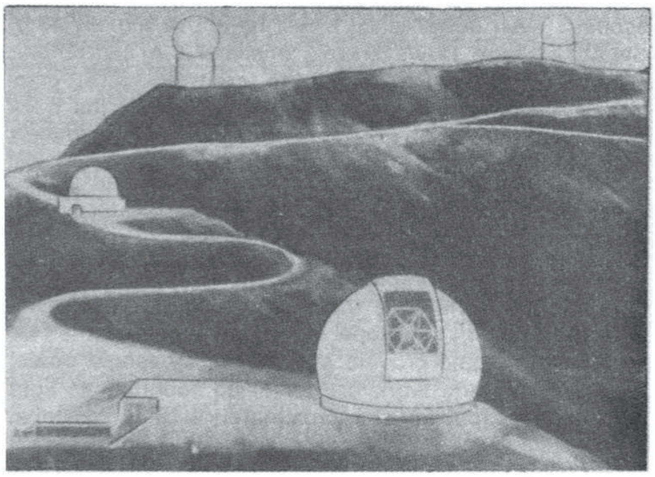
At the ceremony, Dr. Marvin Goldberger, the President of Caltech, said, "Every time an instrument has been introduced into modern science that enables us to explore hitherto inaccessible regimes, we have been shocked and humbled by the unexpected. It is just such a quantum jump in observational astronomy that we will be embarking upon as we break ground for the W. M. Keck Observatory."

Dr. Edward Stone is the Chairman of the Department of Physics, Mathematics and Astronomy at Caltech and also serves as the Project Scientist for JPL's Voyager Project. He gave a talk on the design, construction and potential of the Keck Telescope to an audience at JPL on 2 October 1985.

Stone pointed out that Caltech's 5 m Hale Telescope at Palomar is still the premier instrument in astronomy even though it was designed 50 years ago (it went into operation in 1948). For a scientific instrument to dominate its field for so long is unusual in modern science. One reason is the fact that it represents the end point of a certain technology: the massive, large mirror held together by mechanical strength. It would be difficult to build and support mirrors significantly larger than the 5 m slab of glass.

The 10 m Keck telescope will be built by Caltech and the University of California, to be placed atop Mauna Kea, Hawaii for the start of observing in 1992. The Palomar telescope has a 5 m main mirror.





In this artists s concept, the dome of the 10 m Keck Telescope on Mauna Kea, Hawaii is shown in foreground. Other existing international facilities in the background combine to make the area on top of the 4150 m dormant volcano one of the major astronomical sites in the world. *CARA*

The segmented Keck mirror will consist of 36 hexagonal mirrors, each of which can be relatively thin and light since it rests only in its own support. Stone said that two fundamental items of technology had to be addressed prior to undertaking the 10 m mirror:

(1) Devising a method for shaping each of the 36 constituent mirrors; unlike a mirror for a single-mirror telescope, they will not be axially symmetric. Most methods apply to the symmetric case.

(2) Developing an accurate way to monitor and control the position of each of the individual mirrors so as to coordinate their light-gathering activity into the formation of a sharp image.

Both problems were solved by Dr. Jerry Nelson and his associates at the University of California. Nelson is the Project Scientist for the Keck endeavour, while Jerry Smith of Caltech is the Project Manager. Smith formerly managed the development of NASA's 3 m Infrared Telescope Facility and the Infrared Astronomical Satellite (IRAS). See the April 1984 'Space at JPL.'

The 1.8 m mirrors will be shaped by 'stress mirror polishing.' In this method, levers applied to the perimeter of each mirror distort its shape in such a way that it can be polished with axially-symmetric methods and then, when the levers are released, voila! – the mirror's shape slithers into the desired, non-axially symmetric configuration. Of course, the method requires iteration through several stressing, polishing and measuring steps.

The second piece of technology employs two displacement sensors on each mirror edge (168 in total). These sensors, accurate to 1/200 of the wavelength of light, measure the positions of the individual 7.5 cm thick mirrors and report their results to a controlling computer. The computer controls three motor-driven screws per mirror and effects positional corrections, accurate to 1/50 wavelength, every second.

The performance of the Keck Telescope, according to Stone, is a function of both its size and its location. For example, compared to the 5 m telescope at Palomar, it will be 16 times more effective in stacking up photons. A factor of four is obtained from the doubling of mirror diameter and a second factor of four results from the improved seeing (perhaps 0.5 arc second compared to 1 arc second) on Mauna Kea, which has only 10% of the water vapour and 60% of the atmosphere at sea level.

Of course, the seeing for NASA's Hubble Space Tele-

scope is even better since it will be above almost all of the atmosphere. However, this smaller 2.4 m instrument, scheduled for launch into Earth orbit in 1986, does not have the raw light-collecting capability of the Keck telescope. It will excel in producing high resolution images free from atmospheric smear. The Keck telescope will collect photons from faint galaxies, over 12,000 million light years distant, allowing spectroscopy to be performed for these far objects.

A site has been prepared adjacent to that of the Keck Observatory in the hope that future funding could result in a second 10 m telescope. Operating together, the two instruments would provide a facility of awesome power for interferometric work or, conjoined together as light buckets, the capability of approximately a 15 m telescope.

ICE BISECTS GZ

It was a time for superlatives. On 11 September 1985 the International Cometary Explorer (ICE) successfully accomplished the first encounter with a comet as it passed through the tail of Giacobini-Zinner (GZ). The set of fields and particles instruments (no imaging) onboard ICE registered dramatic changes during passage through the ion tail, estimated to be 15,000-20,000 km in diameter at the (central) chord of crossing.

The story of how this NASA/Goddard mission was diverted from its original functions in the Earth-Moon system to go off to a comet is one of the most dramatic tales in astronautics history (some of the earlier history is contained in the November 1984 writeup in *Spaceflight*). The comet mission was the idea of Dr. Robert Farquhar of the Goddard Space Flight Center, who combined intelligence with persistence to bring about the final result.

One of the components of this success was the accurate navigation of ICE to the centreline of the tail 8000 km from the nucleus. Missions such as Voyager and Galileo supplement radiometric tracking data, acquired by the antennae of the Deep Space Network, with optical images of the target (satellite, planet) taken from the spacecraft. The latter data type is extremely important for these deep space missions, which would not be possible without it, since the camera images establish the relative location of spacecraft with respect to target. With no onboard camera, ICE was denied this data type. Closer to Earth than Voyager or Galileo, ICE had a chance to recoup using Earth-based measurements. Thus, the ICE navigators were faced with the necessity of accurately determining the ephemerides of both the spacecraft and the comet in order to bring them together.

When the comet was recovered by Earth-based telescopes early in 1984, as it approached the Sun in its 6.5 year orbit, its positional uncertainty was on the order of 100,000-200,000 km. Since, at that time, the tail of GZ was thought to be only 5000 km in diameter, the navigators clearly had their work cut out.

Dr. Donald Yeomans of JPL led the effort to improve the orbit of the comet and Dr. Leonard Efron, Chief of the ICE navigation team at JPL, was responsible for determining the orbit of the spacecraft. We will examine these efforts in turn.

Yeoman's task began with the recovery of GZ in April 1984; now Earth-based telescopes could supply positions of the comet as measured against the background of stars.

The optical tracking network was assembled under the auspices of the Astrometry Network of the International Halley Watch and eventually supplied 814 data points from 61 observatories from GZ recovery up to 6 September 1985, five days before the encounter. Major observatories, e.g., Lick in California, worked along with amateur astronomers in a world-wide endeavour to characterise the motion of GZ. Not only were careful astrometric measurements necessary, but they had to be done with respect to a special set of accurately-known stars prescribed by Yeomans (essentially stars from the fundamental AGK3 catalogue).

Time became the essence as the day of encounter approached. Many observers took their observations, reduced the data and telexed the results to Yeomans immediately. He cites as an outstanding example Brian Manning of Stakenbridge Observatory in Worcestershire, England, who used a 26 cm reflector to generate an expeditious and accurate stream of data.

The determination of the orbit of GZ came from folding these observations into a mathematical model of the comet's notion. A particular problem surfaced in the case of GZ. Not only is the motion of the comet shaped by the gravitational attraction of the Sun and planets, but also by non-gravitational forces that change relatively rapidly, on a time scale of months or years. Non-gravitational forces exist for Comet Halley too, but they generally vary only slightly over a period of centuries. One model that would explain the rapid variation of non-gravitational forces on Comet GZ postulates a very flattened cometary nucleus that wobbles or precesses. Then, sites of expulsion of mass from the nucleus would change their inertial direction of force on the nucleus as it wobbles. Expulsion of mass generates forces on the comet by Newton's Third Law.

Yeomans fed GZ ephemeris updates into the ICE navigation process throughout the mission. The last update was sent to Goddard the morning of Friday, 6 September. Over the next day, manoeuvre analysts at the NASA centre computed the last engine burn of ICE and executed it on Sunday, 8 September, three days before encounter. Yeomans estimated that he had determined the final orbit of GZ to within 500 km, relative to Earth. Later analysis of additional cometary observations indicated that his accuracy might have been even better.

The second part of orbit determination for the ICE mission, spacecraft location, proceeded in parallel with the cometary ephemeris improvement. The raw materials for this process were two-way doppler data (S-band) and range data. These data measure the velocity and distance of the spacecraft relative to the observer on Earth and are used in conjunction with a mathematical model of the craft's motion – analogous to the way that optical observations are used with regard to the comet's orbit. A complication for the ICE mission came from the fact that the comet's mass was too small to affect, to a sensible degree, the motion of the spacecraft – so another potential source of comet/spacecraft relative location was not available.

As ICE approached its target, three final trajectory correction manoeuvres (TCM) were done by Goddard in response to the navigational information provided by Efron and Yeomans. The first took place on 7 June 1985 and allowed Efron's team to monitor the performance of the spacecraft's engine. Utilising this experience, they were able to assist controllers at Goddard in tuning the burn parameters while the second burn was in progress, on 9 July. This action was possible because the TCMs were each done in segments, with time between each.

The final TCM, as noted, took place on 8 September. Efron estimates that it delivered the spacecraft to within 50 km of its targetted position relative to Earth. Then the relative position of ICE and GZ was inferred from each of their separately determined positions relative to Earth. Fitting the spacecraft and comet together in this manner is reminiscent of the civil engineer's 'blindfold' trick of

steering two tunnel drillings together under a mountain.

Efron was present at the control centre at Goddard on the day of encounter. He describes the event: "Everyone anxiously scanned visual displays monitoring antenna signal-to-noise ratios and spacecraft solar panel output current (reflecting concern for comet dust coating the panels). Cautious optimism turned into elation as 11.06 GMT came and passed. We knew the instruments had been recording notable levels of activity for some time, but smiles now spontaneously appeared when spacecraft survival had become a reality... a comet had been encountered."

LIFE IN THE COSMOS

From time-to-time in these pages, the subject of SETI, the search for extraterrestrial intelligence, has been discussed. This topic is only one in a broadly-based set of investigations that are now taking place concerning the fundamentals of biological science.

At the coarsest level of resolution one can distinguish three areas of research: (1) the formation and distribution of chemical precursors of life, (2) the origin of life, and (3) the mechanisms of evolution. The first subject has been addressed in a recent NASA publication, *The Cosmic History of the Biogenic Elements and Compounds* (NASA SP-476 edited by John Wood of the Harvard-Smithsonian Center for Astrophysics and Sherwood Chang of the NASA Ames Research Center), and will be reviewed here. A recent theory of the origin of life, due to A. G. Cairns-Smith, will also be examined. Although the theory of Darwinian evolution is itself undergoing a period of rapid evolution, space here does not permit an adequate progress report; the interested reader should consult an article by G. L. Stebbins and F. J. Ayola in the July 1985 *Scientific American.*

When it all began, at the Big Bang, the expanding Universe that was created consisted mainly of hydrogen and helium, with very little of the heavier elements in evidence. In particular, the biogenic elements carbon, nitrogen and oxygen were absent. Thus, the first generation stars that formed were composed only of hydrogen and helium, and we would not expect these systems to be abodes for life as we know it. This type of first-generation (or early generation) star can be found populating globular clusters. Somewhat more than 100 of these ancient objects form a spherical halo about our Galaxy – each is composed of approximately 100,000 stars.

During its prime, a first generation star produces energy by nuclear fusion reactions that convert hydrogen into helium. Later in the life of the star, the helium itself becomes a fuel and nuclear reactions turn into heavier elements, including carbon and oxygen. Some of the biogenic elements are then present in the Universe but are seemingly sealed in the interior of their source of origin. Fortunately (for us), processes exist that break the seal and distribute the elements for general use, including the needs of biology. The most dramatic of these processes is the sudden expulsion of large amounts of material by the star if it becomes a supernova or a nova. A second, more gentle method of distribution is by continuous mass loss through stellar winds (flows of energetic ions that depart from the star). The solar wind is a prominent feature of our environment and has been intensively studied by numerous space missions, including the recent AMPTE project.

The second generation stars that form from the interstellar medium have available to them from the star heavier elements. This fact allows more complex nuclear reactions to proceed and, as a result, the biogenic element nitrogen is produced and eventually disseminated into the interstellar medium by the processes discussed above.

The interstellar medium is not a homogeneous collection of atoms. This breeding ground for stars contains ions, dust and molecules of some complexity, along with atoms. The interstellar medium is, in addition, segregated into rather dense molecular-cloud regions and almost empty intercloud regions. The latter regions are not favourable for the development of complex molecules because ultraviolet radiation from nearby stars continually breaks chemical bonds. The interstellar clouds do not provide a hospitable region for molecular building programmes, and many species have been detected through astronomical observation in recent years.

A star is created by gravitational collapse and heating in part of an interstellar cloud. However, not all of the collapsing material feeds into the star-to-be. An accretion disc can form; it consists of material lying nearly in a plane and rotating about the protostar.

For later generation stars, such as the Sun, the accretion disc will contain biogenic elements and their compounds. If planets subsequently form in the accretion disc (called the solar nebula in the case of the Sun), some will be stocked with the raw materials that life-as-we-know-it requires.

The material from the now-vanished solar nebula is still available for study; it has been locked into comets. As Wood and Chang express it, "Comets are the repositories of the most primitive, best preserved, but most fragile nebular and presolar materials still surviving. We study them from afar with intense interest, and yearn for the opportunity to send spacecraft missions to them."

In the 1920's the Russian A. I. Oparin and the Englishman J. B. S. Haldane formulated the 'warm pond' theory of the origin of life. Given biogenic materials discussed above, and some additional chemical evolution in the waters of the early Earth, life arose as increasingly complex organic molecules developed and learned to replicate themselves. This scenario, considerably amplified by biochemists over the years (there is a journal *Origin of Life* devoted to this and allied topics), is still the most widely accepted theory explaining how life arose on Earth.

However, some biologists have felt that the probability of molecules arranging themselves by chance in the intricate patterns required by even primitive life is too small to provide credence to the warm pond theory.

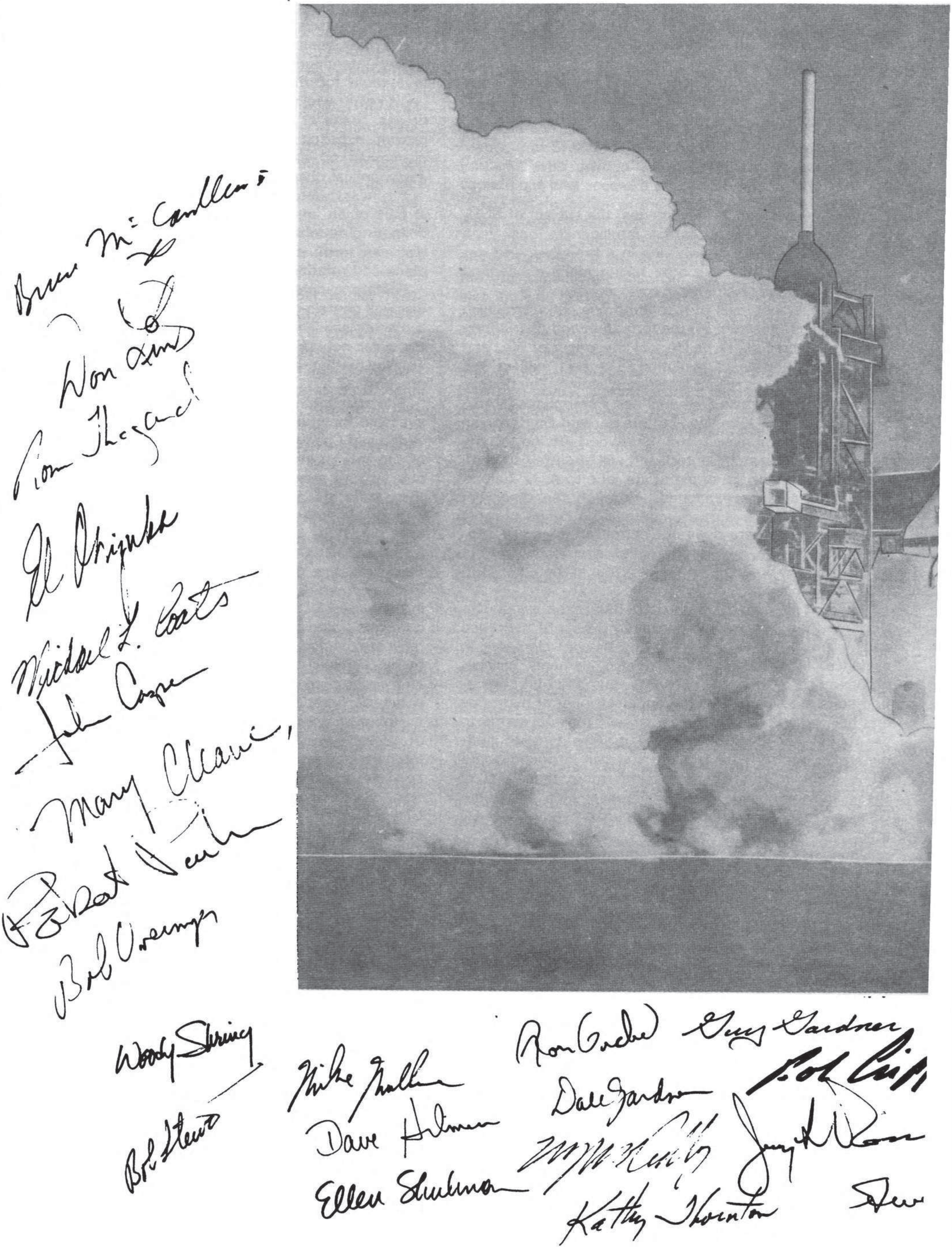
A. G. Cairns-Smith, a chemist at the University of Glasgow, takes issue with the conventional theory of the origin of life. His book *Genetic Takeover and the Mineral Origins of Life* (Cambridge University Press, 1982; see also his article in the June 1985 issue of *Scientific American*) proposes that life did not start with carbon chemistry. It came into being from highly ordered crystal structures, perhaps in certain clays, which themselves were capable of reproduction and only later became 'filled in' with what we recognise today as organic compounds.

The crystals of Cairns-Smith are clay minerals like kaolinite and can store the information that life needs through 'defects' which inhabit almost all crystals (thus, a defect can be a virtue!). Crystal growth and cleavage provide ways in which this information can be propagated through time. In a word, Cairns-Smith has functionally outlined a gene but not one made of DNA. The clay 'scaffolding' was gradually taken over by what we describe as organic molecules and the normal processes of Darwinian evolution could begin.

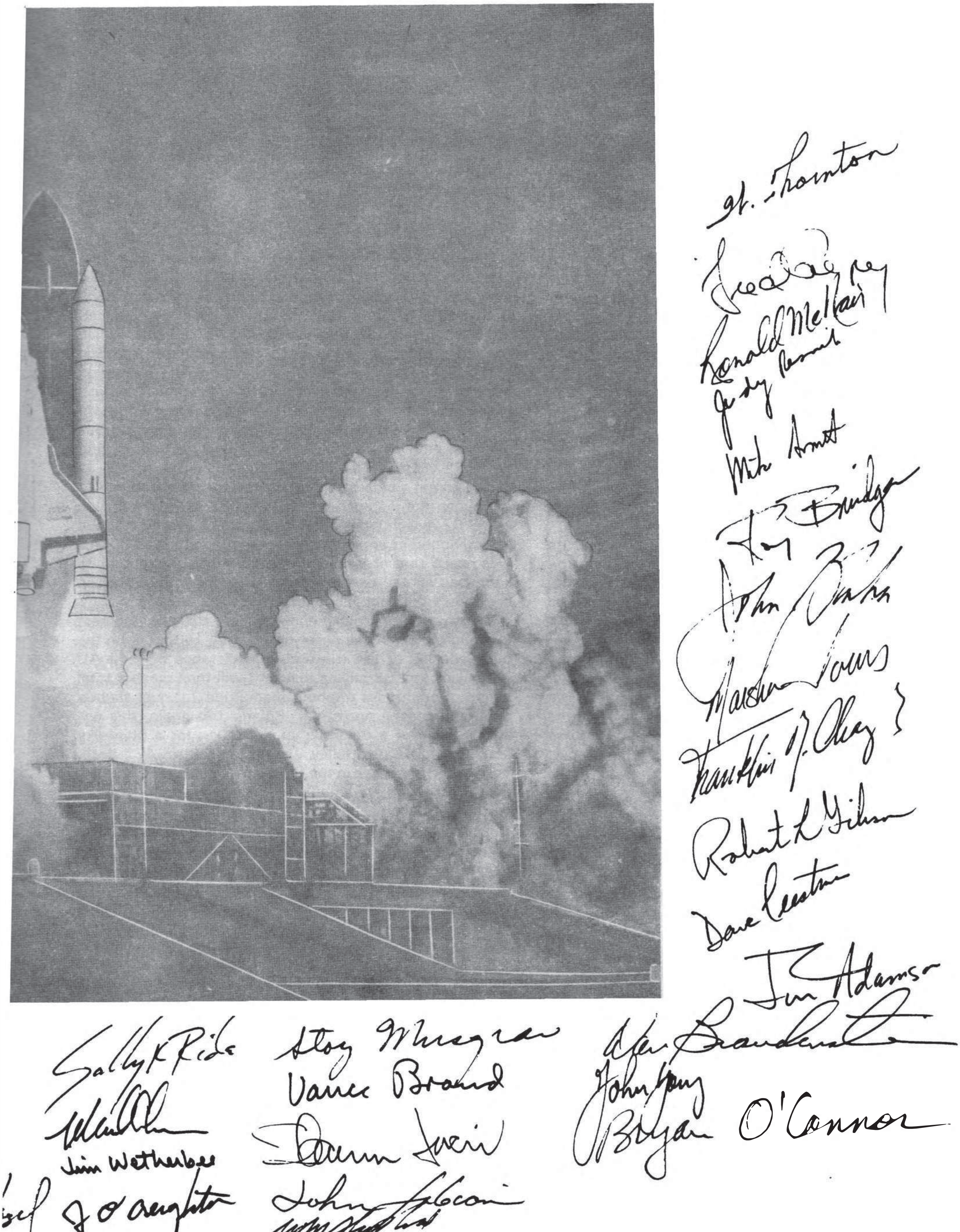
The theory of Cairns-Smith will have to be tested in the scientific arena, but it clearly has some attractive features and, if correct, may bolster the position of ETI theorists who believe in the abundance of life in the Universe.

PRESENTATION TO THE SOCIETY

The Society wa
Additionally, ma
thanks to each



...eatly honoured to receive the Shuttle launch picture reproduced below. It bears the signatures of 46 US astronauts. ...thers, unavoidably absent at the time, have asked to be associated with the gift. The Society expresses its grateful ...aut individually, and to Tony Smith who dealt with the matter so magnificently on our behalf.



Compiled by L. J. Carter

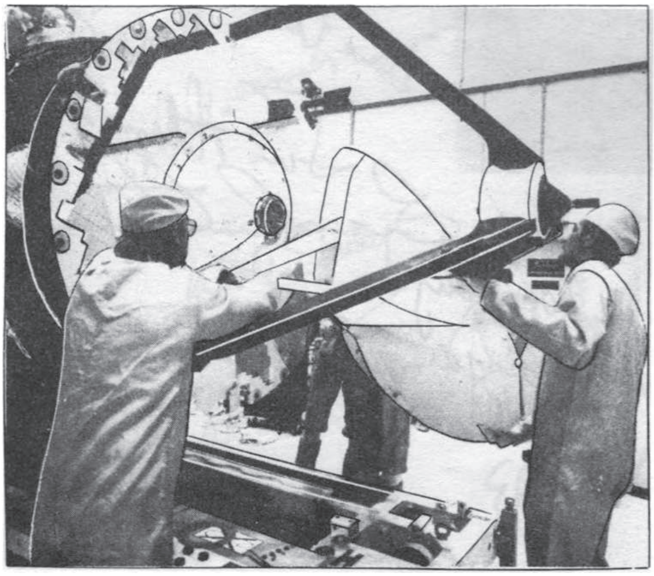
WELL ON THE WAY

Halley's comet has been on the inbound leg of its journey round the Sun since its aphelion in 1948. At that point it was 35.25 AU (5,270 million km; 3,275 million miles) from the Sun, well beyond the distance of Neptune and moving at only 0.91 km/sec. (2,000 mph). Perihelion, the point of closest approach to the Sun, will occur on 9 February 1986. The comet will then be only 0.5781 AU (87.8 million km; 54.6 million miles) from the Sun, well inside the orbit of Venus and moving at 54.55 km/sec (122,000 mph).

The comet was first observed on its return to the inner Solar System on 16 October 1982 in images obtained by Caltech astronomers G. Edward Danielson, David C. Jewitt and co-workers using the 200-inch telescope at Mount Palomar Observatory.

By early autumn 1984, observations showed that its coma - the bright halo of dust and gas surrounding the nucleus - had already begun to develop, with astronomers now questioning why it began to exhibit this feature so far from the Sun. Early observations also showed that Halley's brightness was fluctuating, again to their puzzlement. Even so, viewing conditions for this 30th recorded appearance will not be as good as those during the last apparition in 1909-1911 because of the different relative positions of the Sun, Earth and the comet. In fact, the comet this time will appear much less spectacular than at any other during the past 2,000 years. Estimates of Halley's brightness during earlier returns are based on the comet's closest passage of Earth and the assumption that it behaved as it did in 1909-1911, when it reached a total apparent brightness of about magnitude -1 and passed within about 0.15 AU [23 million km; 14 million miles] of Earth.

Installation of the dish antenna on the Giotto spacecraft during launch preparations.



Comet Halley moves backward (opposite to Earth's motion) around the Sun in a plane tilted 18° to that of the Earth's orbit. This retrograde motion is unusual among short-period comets, as is its aphelion distance beyond the orbit of Neptune. Its period averages 76 years, which corresponds to an orbital circumference around the Sun of 12,200 million km (7,600 million miles). The period actually varies from appearance to appearance because of the gravitational effects of the planets. Measured from one perihelion passage to the next, Halley's period has been as short as 74.42 years (1835-1910) and as long as 79.25 years (451-530).

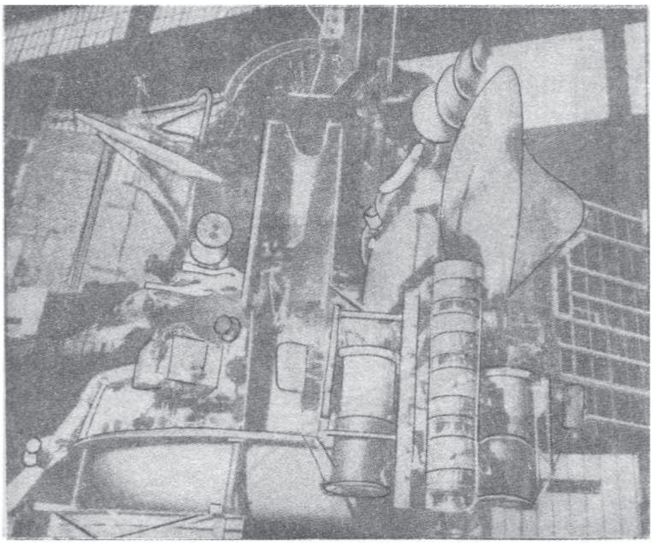
The comet's closest approach to Earth occurred in 837 AD, when the distance was only 0.033 AU (4.94 million km; 3.07 million miles). On 10 April 837, Halley reached a *total* apparent brightness of about magnitude -3.5. This was nearly that of Venus at greatest brilliance though its light was spread over an extended area and its surface brightness thus actually fainter.

During the current appearance, Halley's nearest approach to Earth will occur on 11 April 1986, i.e. on the outbound leg of the trip and at a distance of 0.42 AU (63 million km; 39 million miles). It will then reach a total apparent brightness of about magnitude 2.0, just slightly brighter than the north star, Polaris, but again, this will be spread over a much larger area than for a point-like star. On that date, Halley will be far south (-47° declination) and best seen in the Southern Hemisphere, actually passing through the zenith for observers at 47° south latitude. The comet will be very low in the sky. Inbound to the Sun, Halley will make a close approach to Earth on 27 November 1985, at a distance of 0.62 AU (93 million km; 58 million miles).

Among short-period comets, Halley is judged to be large. Its nucleus is believed to be an irregularly shaped sphere, roughly 6 km (4 miles) in diameter, rotating approximately every 2.2 days. The axis of the nucleus is tipped perhaps 45° to the orbit plane. The estimated mass is 100 million million kg.

During the peak of spacecraft activity, on 10 March 1986, the nucleus is expected to produce gas at a rate of 8×10^{29} molecules per second; of this, some 80% is expected to be water. Seen another way, this production is equal to 3,000 kg/s (6,600 lb/s). Estimated dust production on that date: general, 600 kg/s (1,300 lb/s) and, in jets, 900 kg/s (2,000 lb/s), for a total of 1,500 kg/s (3,300 lb/s).

The dust emitted by the nucleus will extend roughly 100,000 km (60,000 miles) in the sunward direction and twice that distance perpendicular to the sunward direction in mid-March 1986. Various gases will extend far beyond these distances, but the *visible* gas coma will probably be no larger than the dust coma. The visible gas is largely composed of C_2 (molecular carbon) with small



The Soviet Vega probe.

contributions from many molecular fragments containing such elements as carbon, hydrogen and nitrogen (C_3, CH and CN, for example). Various visible coma structures will be the product of dust jets.

The ion and dust tails of Halley should become fairly well separated. In mid-March 1986, the ion tail should extend about 15° - representing a maximum length of about 80 million km (50 million miles) - in the direction opposite the Sun. At that time, the dust tail will appear to be spread out like a fan, rather than edgewise as in 1910. It will appear to the north of the ion tail as a sort of heart-shaped blob, 2° in length, with its point at the coma. (For scale, the Moon is about half a degree in diameter). Both tails will be visible only in clear, Moonless skies far from any city lights and air pollution, looking like faint, misplaced pieces of the Milky Way.

With each orbit around the Sun, the comet loses an estimated 1-3 m (3-10 ft) of material from the surface of its nucleus. Thus, as it ages, it dims in appearance and may eventually lose all the ices in its nucleus. The tails disappear at that stage and the comet finally evolves into a dark mass of rocky material or dissipates into dust.

It is estimated that an average periodic comet lives to complete about 1,000 trips around the Sun. Halley has been in its present orbit for at least 16,000 years but has shown no obvious signs of aging in its recorded appearances.

The NASA Hubble Space Telescope, scheduled for launch in August 1986, will track Halley on its way back out of the inner Solar System, perhaps all the way to its point of aphelion, 3,280 million miles from the Sun.

All properly documented Halley data obtained from Earth and from space will be stored and then published by the International Halley Watch in 1989 as an archive for use by researchers until the comet next returns in 2061. Data will appear both in book form and on digital videodisc for easy computer analysis.

INTERNATIONAL MEETING

Representatives of the space agencies of Europe, the Soviet Union, Japan and the United States met in Washington DC from 10-12 September to continue discussions on a broad range of cooperative activities in the investigation of Halley's comet. A unique aspect of this meeting was the opportunity to follow NASA's ICE (International Cometary Explorer) spacecraft encounter with the Comet Giacobini-Zinner on 11 September. This was the first time

COMETS GENERALLY

Our knowledge of comets is limited, even for those seen in recent years. This is because the nucleus - which is the real comet and the source of the visible coma and tails - is too small to be seen other than as a point of light. Only our knowledge of cometary motions is on reasonably firm ground.

Comets are believed to have condensed from the solar nebula at the same time that the Sun and planets formed, about 4,500 million years ago. Most are thought to reside in the furthermost reaches of the Solar System, 30,000 to 70,000 astronomical units from the Sun. This distant aggregation from which comets are gravitationally 'pulled' is known as the Oort Cloud, after the Dutch astronomer Jan J. Oort (1900-), who originated the idea, though recent evidence suggests that the region from 1,000 to 30,000 AU might also be heavily populated.

It is believed that comets remain far from the Sun until they are disturbed by the gravitational perturbations of passing stars and forced into closer orbits. Because of their small size and normally great distance from the Sun, they are believed to be the most pristine, unaltered samples of the early Solar System. Planets, moons, even some asteroids, by comparison, have undergone various changes as a result of melting, volcanism and other processes. This is one reason why there is so much interest in comets. Their unique status may hold many clues to a better understanding of the origin and evolution of the Solar System.

Long-period comets are those with orbits stretching from 200 to many millions of years. They are usually the most spectacular. Aphelion (their most distant point from the Sun) is often more than 50,000 AU away.

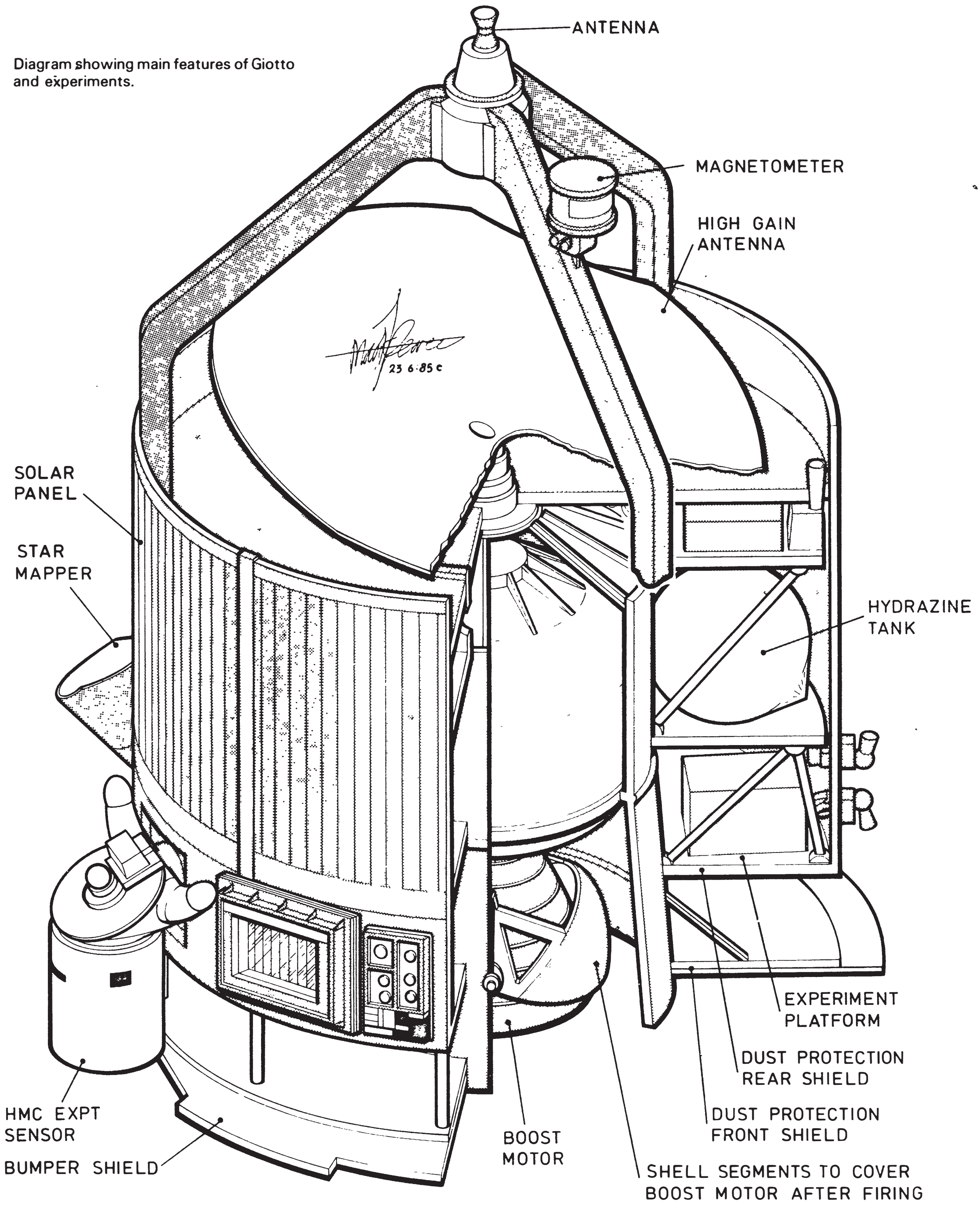
Short-period comets are those with orbits of less than 200 years. Most reach aphelion near the orbit of Jupiter. Of about 100 well-known short-period comets, Halley is the brightest and the most famous. Actually, it belongs to a group now called 'intermediate' period comets, i.e. not short enough to be regularly influenced by Jupiter but still with periods less than 200 or so years.

All comets have two tails. The first is formed when solar heating causes neutral molecules to be shed from the nucleus. These molecules are given an electric charge by solar UV and X-radiation. When they encounter the solar wind and its magnetic field, the then-charged molecules are carried outward to form a tail that may stretch millions of miles through space. This is known as the ion tail, 'ion' being the general term for atoms and molecules that carry an electric charge.

Gases streaming from the nucleus also carry off a fine dust. This dust, blown away from the Sun by the pressure of solar wind, forms a second tail. It is seen by reflected sunlight and is known as the dust tail.

When the two tails are superimposed on each other, as seen from Earth, the comet appears to have only one tail. This happened in 1910 for Halley. For smaller, less active comets, one or both tails may be too faint to be seen or even photographed and the comet will appear simply as a fuzzy blob of light. All comets appear this way when far from the Sun. Tails usually begin to become visible only within about 1½ AU of the Sun.

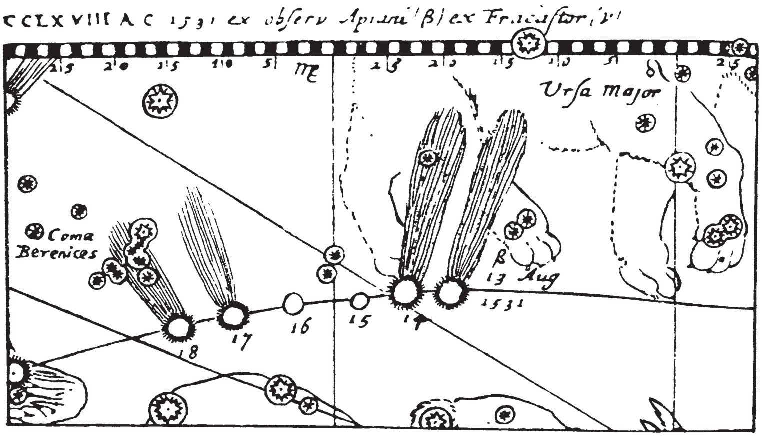
Diagram showing main features of Giotto and experiments.



in history that a spacecraft had flown through, and taken measurements in, a cometary coma and ion tail. The representatives were surprised by the high level of activity displayed in plasma physical processes and by the extent of the solar wind/comet interaction region. These factors are being taken into account in planning mission operations for the March 1986 encounters.

One of the focal points of the coordination is the 'Pathfinder' concept, the joint navigational effort involving ESA, the USSR and NASA. Giotto, which will be the last to fly by the comet, will benefit from data on the position of the nucleus (which is too small to be seen from Earth even with the best telescopes) transmitted by the cameras on-board the two Soviet Vegas which will encounter the comet 7 and 4 days before Giotto. These data will be used to reduce Giotto's targetting error from 300-500 km to about 150 km. NASA will assist in the Pathfinder activities by providing Vega with tracking support from its 64 m deep space antennae in California, Australia and Spain.

On Giotto, 8 out of 10 experiments had been switched on by mid-September for testing and to obtain cruise and science data and also, partially, in support of the Giacobini-Zinner encounter. The remaining two experiments (Dust Mass Spectrometer, Dust Impact Detection System) were switched on in early October.



Observations of Halley's comet in 1531 by Peter Apian.

WATCHING GIOTTO'S HEALTH

Engineers have been monitoring the health of Giotto since launch with a British computer designed primarily to provide advanced communications for large business systems. Information Technology Ltd's Momentum 9000 supermini-computer at the European Space Operations Centre is processing and distributing vast quantities of telemetry data at high speeds despite having only 0.75 megabytes of main memory. This feat is possible because of Momentum's advanced communications architecture, developed to provide fast response for large numbers of varying types of Input/Output devices, such as on a 150-terminal commercial computing system.

Momentum is feeding continuous data on 2,000 Giotto and experiment parameters through an ITL Cablestream Local Area Network selectively into 10 other computers, from Apples to DEC PDP-11s. Momentum's selectable multi-colour synoptic displays of each sub-system also makes satellite and experiment status visible and adjustable without mountains of printouts. Momentum was used as the development base for ETOL, the European space programming language, which allows scientists and engineers to programme their applications without needing to be computer specialists. Cablestream is a range of ITL equipment that makes up Europe's most popular broadband cable local area network (by numbers of installed ports) and is used by many industrial and commercial giants.

RADIO OBSERVATIONS

As Halley's comet approaches the Sun, increasing temperature will cause the sublimation of ices in its nucleus, thought to be really nothing more than a giant dirty snowball. Water molecules liberated and then dissociated by the ultraviolet light will cause it to emit radio spectral lines at 18 cm wavelength by a maser process. The 18 cm lines will appear either as emission or absorption lines depending, in a complicated way, on the exact velocity of the comet relative to the Sun.

Radio observations of the 18 cm lines of OH from Comet Halley will be used to study the production rate of OH, the outflow of gas from the comet, the magnetic field (which may cause a detectable Zeeman splitting of the OH lines), and to test theories of the mechanism of the maser.

A worldwide network of radio telescopes will be observing the comet during its apparition. Jodrell Bank plans to use its 80 m Mk IA telescope to study the comet in January/February 1986, near perihelion. Radio observations will then be particularly useful as the comet will be too close to the Sun for sensitive observations in most other wavebands. During this period, the OH maser is expected to switch several times between emission and absorption, as the comet's heliocentric velocity changes.

HALLEY AND FLAMSTEED

Although Edmond Halley is greatly honoured nowadays, it wasn't always so. A bitter wrangle occurred between Halley and John Flamsteed, the First Astronomer Royal, which was never resolved. Halley had much that was derogatory to say about Flamsteed: the latter responded (in a letter to Abraham Sharp) by called Halley 'a malicious thief.'

Their differences were not due solely to temperament e.g. Flamsteed was brought up on rigorous lines whereas Halley was somewhat intemperate, but to Flamsteed's wish to hold back on publication to enable him to extend and improve his observations.

On the other hand, both Newton and Halley wanted to see his observations and put them to use, the dispute culminating in the appearance of a 'spurious' edition of Flamsteed's observations, edited by Halley, to which Flamsteed responded by buying up as many copies as he could and burning them!

Newton was not above all this. For a long time he was Flamsteed's friend but the dispute grew so bitter that, by reason of his own interest in using Flamsteed's material, he became similarly embroiled.

Review

La Cometa di Halley
P. Maffei, Arnoldo Mandadori, Informazioni Stampa, 20090 Segrate, Milano, Italy, 1985, 418pp.

Those who understand Italian will much enjoy this work. Though a paperback it affords a heavyweight introduction to Comet Halley which is not only well illustrated and well printed but which includes many fascinating illustrations, some in colour.

After the general introduction, the book gets into it stride with ancient and medievel accounts of earlier returns, in most cases accompanied by maps showing the paths of the comet across the celestial sphere. More recent returns are written up extensively, culminating in the 1985/86 apparition which is dealt with in considerable detail and which includes the appropriate star maps and similar information to enable the comet to be readily discovered.

It is greatly to be hoped that the book will also appear as an English edition.

HALLEY'S COMET IN 1910

By H.J.P. Arnold

As Halley's comet speeds toward the inner Solar System, it is understandable that the events of the last 'apparition' in 1910 should be receiving considerable attention. Since that visit was the first to take place in the era of mass newspapers, the manner in which the event was presented to the public, together with the public's reactions, is of particular interest.

Introduction

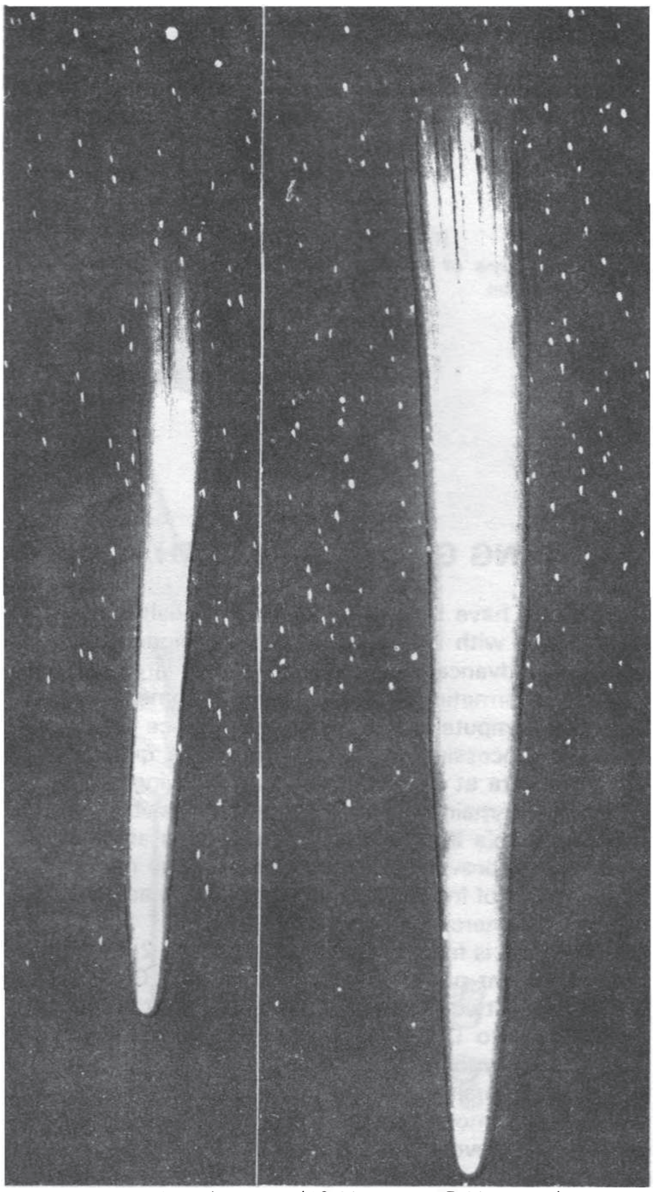
Until now this line of research has tended to concentrate on *national* newspapers and magazines, with the result that the provision of information and reactions at the 'grass roots' level have received little attention. This brief account makes such a local evaluation - for Portsmouth in Hampshire - drawn largely from the pages of *The Evening News,* the area's daily newspaper. In 1910 Portsmouth (chiefly famous for its Royal Navy dockyard which for some years had been leading the *Dreadnought* capital ships building programme), was a large city with a population of more than 230,000. *The Evening News* had a circulation of about 60,000 and the price was 'One Halfpenny.'

An Unexpected Visitor

Paradoxically, the story starts in January 1910 with news of another and totally unexpected comet: the discovery of what came to be called the Great January or Daylight Comet. Following two brief announcements on 19 and 20 January, *The Evening News* of the 22nd went into some detail and reported sightings from around the country and locally. Under the heading 'The New Comet. Where to Look...,' it quoted Mr. Victor Pink of the local company Pink & Sons as having seen the comet from Cosham (near Portsmouth) the previous evening 'below Venus and a little to the right at around 5.30 p.m. while returning home from Horndean on the light railway.' The report then went on to quote authoritative comment from members of the Royal Greenwich Observatory, something that it did consistently in the next few months. E.W. Maunder of the Observatory (a solar specialist but also a great popularizer of astronomy), in a report drawn from the previous day's *Daily News,* stated that 'It is unusual for a comet to be readily seen by the naked eye, even at night; but it is extraordinary for one to be visible in full daylight.'

In subsequent issues, the position of the comet was helpfully given to readers, together with details of observations from around the country as well as the Portsmouth area. On Monday 24 January, a report described the comet as being 'very beautfiul' and resembling the 'gorgeous tail of a bird of paradise.' It had been seen by many Portsmuthians on the previous Saturday evening when 'Quite a large crowd gathered on Fratton (railway) Bridge about half past five and had a remarkably good view of the visitant in the western sky. The comet was likened to a falling rocket (but) one lady exclaimed to her husband, who had occupied five minutes in directing her gaze at the wonder "Is that all!" '

In the same story, comments by Sir Robert Ball, Lowndean Professor of Astronomy and Geometry at Cambridge University, were neither academic nor dry. He concluded 'And the wonder of it all is that in a few days more the (Daylight) comet would go back to infinity, never to appear again. We do not know whence it comes, nor whither it is going.'



Two images of Halley's comet (12 May left; 15 May right) acquired from Honolulu. The tail in the right image stretches some 40°
Hale Observatories

A.C.D. Crommelin at Greenwich (a comet specialist and one of the two men who had done excellent work in calculating the orbit of Halley's comet for the 1910 apparition) took the opportunity to bring the subject around to that more famous (if potentially less spectacular) visitor in *The Evening News* of 27 January by advising 'all observers to be very watchful, because it (Halley's) was rapidly approaching the Sun and at any time it might develop a tail... It will not be visible to the general public until towards the end of April and the beginning of May.'

Of even greater help to the general public was an article that had appeared in *The Evening News* on 21 January which, among other points, cautioned readers that 'The new comet is not to be confused with Halley's comet, which is still a faint telescope object and will not be conspicuous to the naked eye until the last fortnight in May. Bright comets, with the single exception of Halley's, are always unexpected visitors, and the new comet is a further example of the rule.'

As February approached, the stories became quite technical and one - on 3 February - reported that the

comet's orbit had finally been computed accurately but that 'Comet 1910A' - its official astronomical designation - was 'growing fainter.' But it had been spectacular and so far as the general public was concerned its brilliance was to compound the disappointment felt at the appearance of its more illustrious successor.

The Arrival of Halley's Comet

The coverage of the Haliey's comet visitation in *The Evening News* can be divided conveniently into the period up to the middle of May 1910, when the newspaper published extremely detailed and well-informed stories on the comet's progress but with limited local content; the period just after the middle of the month at the time of the comet's transit (passing in front) of the Sun and the possible passage of the Earth through its tail; and then the period from the second half of May into early June when coverage remained extensive with interesting local reaction. Throughout this coverage the newspaper combined expert comment (usually from members of the Greenwich Observatory quoted in national publications) with reports from around Britain and the world, again normally quoting correspondents of the national and international press.

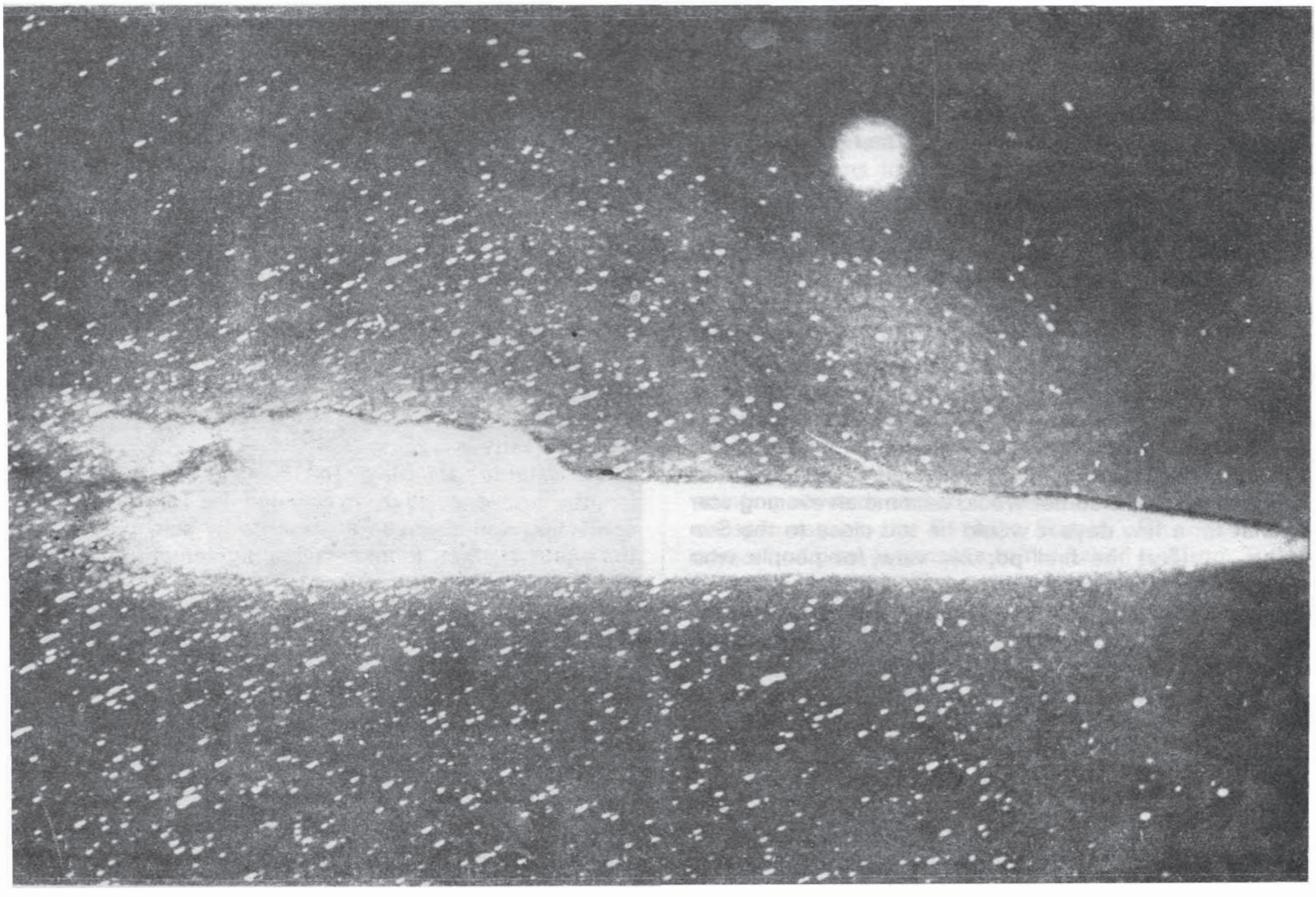
The Hampshire Telegraph (a weekly sister paper of *The Evening News*) described an early local observation on 7 May when Mr. M.J. West of Gosport (on the west side of Portsmouth Habour), who was 'much interested in the science of astronomy,' wrote that having failed to locate Halley's comet on several mornings over the previous fortnight, he finally found it with the naked eye between 3.10 and 3.20 a.m. on Tuesday (3 May) from the Recreation Ground at Gosport. 'I also saw it through a low power telescope and although it appeared much larger than when I got my first telescope view of it on 9 February, it did not show much of a tail, which was not surprising in consequence of its low altitude and the approaching dawn...'

Mr. West in Gosport was evidently an experienced observer and an early bird in more senses than one so far as anybody but the professional astronomers was concerned. Crommelin at Greenwich was again quoted in a lengthy article on 10 May. This gave an outline of Halley's history and in particular the quite unjustified association with disasters of one kind and another. On the current apparition, he told his audience at the Victoria Institute in London that, in the last ten days of May, the comet would 'give a fairly good display as an evening star, though it was only right to warn those who saw the great comet of 1882 that Halley's would not compare with it from a spectacular point of view.' (Oddly, Crommelin does not seem to have referred to the brilliant daylight comet a matter of just a few weeks earlier). He went on to add that the ancient records of the brilliance of Halley's comet 'led him to believe that it had declined as the centuries passed.'

Public Alarm

By this time the alarm felt at possible death and destruction resulting from the visitation, and especially the allegedly poisonous effects of passing through the tail, was in full flow. This has been extensively treated in the Halley literature but *The Evening News* gave additional insights. On 13 May, for example, it carried a delightful item quoting Padre Alfani of the Ximenes Observatory who, in a lecture at Florence, sought to ease his audience's worries ('the chances of (the comet) doing any damage to the Earth were a hundred thousand millions to one') and went on to quote the case of 'A man (who) came to him on the previous day to implore him to give a written statement that the comet was harmless, so that he might calm the fears of his mother-in-law.'

The comet and Venus as they appeared from the Lowell Observatory in Arizona on 13 May 1910. The exposure was 36 minutes.



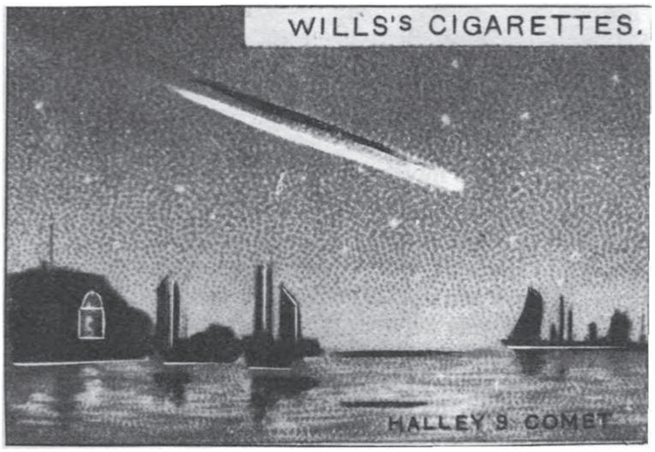
On 14 May (the longest reports appear to have been on Saturdays) the newspaper devoted its story partly to the alleged menace of the comet, partly to scientific reports. Thus the plan of the International Commission for Scientific Aeronautics in the UK to send instruments aloft in balloons 'in view of the possible passage of the Earth through the tail... on the early morning of the 19th' (one of the balloons was due to be launched from a location in Hampshire) was reported, as were accounts of the comet being seen at locations abroad such as Berlin, Aix-la-Chapelle and Odessa. The brightness was quoted as varying from magnitude 1 to 3 - the last (and least bright estimate) being accompanied by the comforting if somewhat puzzling comment that 'this fact now tends to allay the nervous apprehension of the people.' An *Express* report from New York leaned in the same direction. It quoted spectrograms obtained at the Lowell Observatory in Flagstaff, Arizona as showing that the 'dreaded cyanogen gas,' which was supposed to be one of the constituents of the comet's tail, was confined to the head. 'Hence there is no danger of the poisonous gas reaching the Earth.'

Comet's Vapours like 'Kirsch Liqueur'

Also intended to put people's minds at rest were comments attributed in the same *Evening News* story to a report in the *Standard* from Paris of a letter laid before the Astronomical Society there by Camille Flammarion, director of the Juvisy-sur-Orge Observatory and a well-known populariser of science, especially astronomy. Flammarion appears to have adopted a rather quixotic role during this period, starting as many scares as those he attempted to scotch. However, on this occasion he described wild predictions about the comet as being 'only worthy of barbaric ages' and criticised the 'necromancers and such like charlatans (who) were driving (sic) a great trade just now (while) many educated people who ought to know better were sealing up their windows and doors... to protect themselves against the dreaded tail of the coming visitant.' Flammarion predicted confidently that inhalation of any of the comet's diluted vapours 'would resemble that of a glass of Kirsch liqueur and would be simply exhilarating.' Quite why the comet should be associated with a spirit distilled from the fermented juice of a black cherry was not explained!

While the death of King Edward VII early in May doubtless provided the doomsayers with further evidence of the comet's malevolence, *The Evening News* on 18 May (the day of Halley's transit of the Sun) adopted a bantering tone. Its story was sub-headed 'Twixt Earth and Sun to-night' and began 'To-night Halley's comet passes between the Earth and the Sun, and we are looking forward to being whisked by the end of its tail.' It stated that the tail was now about 14,500,000 miles long and that 'we may just be flicked by it between midnight and three a.m.' *The Evening News* advised its readers that after the transit the comet would become an evening star but that for a few days it would be too close to the Sun to see. '... (For) the first popular view for people who object to leaving a warm bed at half-past two in the morning, and going to a high place, we shall most likely have to wait until Saturday.'

Very lengthy coverage on the following day (19 May), while briefly quoting a Greenwich Observatory official on the chances of seeing the tail from Britain, concentrated on foreign reports under the sub-heading 'Serious and Comic Results.' The San Remo correspondent of the Paris *Journal* reported that one man had jumped into a well and drowned and that another 'not wishing to wait for the comet, killed his wife with a hatchet and afterwards hanged himself from a tree.' But mostly the touch was light. In France the subject was being treated 'in a spirit of light hearted banter' while Germany was indulging in 'popular festivities.' In Rome it was like New Year's Eve with cafes and restraurants remaining open all night. Most people in Spain were celebrating the transit 'with great joy' and in Madrid 'to the sounds of guitar and tambourine' they were going to 'elevated positions to view the comet which however will probably not be visible as the sky is overcast.' This last report continued: '(Far) from being... the subject of superstitious terror, the passage of the comet and its terrible tail close to our planet forms, on the contrary, a cause of mirth and of entertainment, gastronomic as well as astronomic, for families can be counted by the hundred who, the better to observe the vagabond orb, have laid in plentiful supplies to fortify them in their vigil.'



Halley's comet continued to be a popular astronomical theme long after the 1910 appearance. This is a cigarette card issued c.1928.

There was some serious scientific comment on 19 May (and an indication of good weather in the USA at least) when the distinguished Professor Barnard of the Yerkes Observatory was quoted as saying delightedly that the comet was 'a most striking object, brighter than any portion of the Milky Way and it could be traced a distance of 107 deg...' Whimsy, however, was never far away and another story described strange happenings in Southfields (London) the previous night, where 'myriads of tiny crystals... covered the pavement in all directions and sparkled in the moonlight like hoar frost.' It was a warm night, *The Evening News* observed, yet 'whether the phenomenon had anything to do with the comet, however, is an open question.' More prosaically, but not to be entirely outdone, it reported that in Portsmouth on the same night 'it is stated that the Northern lights were very much in evidence.'

Strange Smells

On Saturday 21 May, *The Evening News* headed its lengthy coverage 'Have we Brushed the Tail?' and quoted conflicting and abstruse arguments by scientists around the world. (In fact, there is still no agreement on whether the Earth passed through the tail in 1910.) While the comet had been a 'magnificent spectacle for many nights' on Mahe in the Seychelles, the Geneva correspondent of the *Daily Chronicle* wrote that 'crowds of tourists, Alpinists and Swiss Scientists have been disappointed as Halley's comet was invisible owing to the clouds.' Camille Flammarion also reported bad weather and more particularly that a watch of five observers at the Juvisy Observatory on the night of 19/20 May noted no instrumental effects of passage through the tail but that 'at about half-past two, four of the observers had certain olfactory

experiences which are described variously as a smell of burning vegetables, of a marsh, or of acetylène. During the night, the nightingale was silent...'

The Evening News writer, however, appeared more taken with the experience of a South Wales magistrate and amateur astronomer who had gone out to observe the comet and was confronted by a detective, who asked what he was doing. 'I am looking for the comet.' 'That's all very well, but I have been watching you for some time now and your movements have been very suspicious.' The detective remained incredulous 'until invited into the house.'

Local Observers

More seriously, there appeared in the 21 May issue a letter from Annie M.H. Sturdee of Southsea, dated 19 May. Miss Sturdee was clearly a keen student of astronomy and wrote how terribly disappointed she had been on the previous night not to see anything of Halley's comet. There had been thunder and lightning and then 'flashes from a searchlight every now and again between 1 and 2 a.m. (which) were unappreciated under the circumstances.' Earlier in the evening, however, she had seen a fan in the sky 'alternate rays of light and dark slightly north of west' which were quickly obscured by cloud but which she was convinced were due to the proximity of the Earth to the tail of the comet. 'The interesting spectacle compensated me for my long and uneventful morning vigil.'

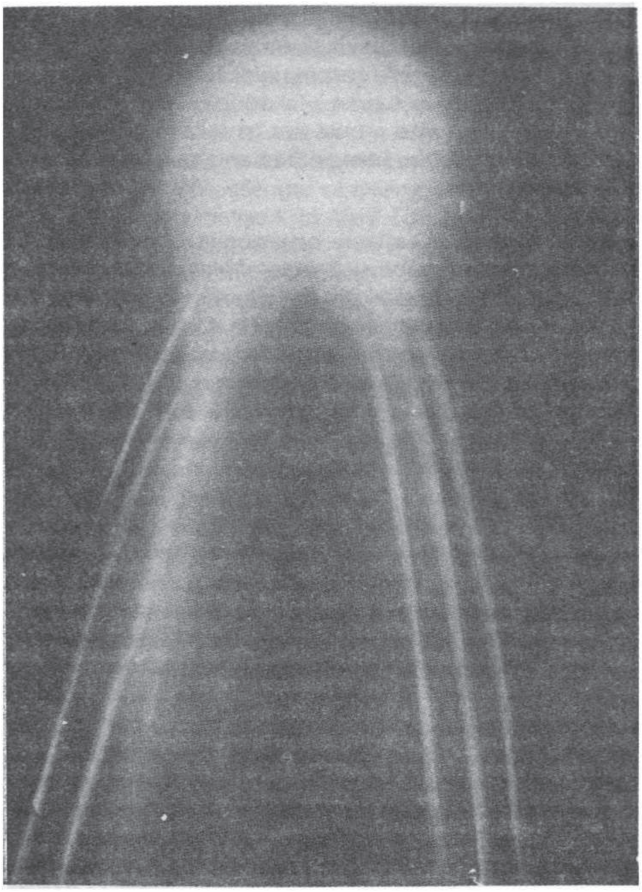
The Evening News obviously believed it had a capable local astronomer in Miss Sturdee since it quoted her on 23 May as saying that 'the last phase (sic) of Halley's comet may be seen early from the (Southsea) Common... between the hours of 9 and 11 p.m. provided the western sky is free from clouds.' She sketched the location of the comet in the sky on the previous evening 'though the clouds prevented a good view' and went on that each night 'the comet will appear a little higher up and further away from Mars as if steering for Regulus (in the constellation Leo). 'Amateur observers will do well,' the perceptive Annie Sturdee continued 'to keep as far away as possible from the electric lights, which are not helpful to star gazers.'

In this same issue, and that of 25 May, while splendidly clear conditions for observing the comet were reported around the world from Johannesburg to Constantinople, Britain had to be content with very patchy visibility to say the least. Good views had been had from Dover and 'glorious visibility' for over an hour and a half at Brunscombe but generally the story was gloomy. London was disappointed in the comet as 'not much to look at,' while to a local Portsmouth correspondent who saw the comet briefly on Sunday night (22 May) from the top of Portsdown Hill (to the north of the city) it appeared rather as 'a blurred star with a diffuse light. As the clouds separated for a second or so, a faint tail could be seen pointing upwards and to the south....It was not nearly so conspicuous as the Daylight Comet.' On 24 May the comet had been just visible to the naked eye from Totland (Isle of Wight) but for the 'large numbers of people... eagerly looking for the comet, the sight they obtained was evidently disappointing.'

The Flammarion story of strange smells published in *The Evening News* of 21 May was taken up in a letter from 'M.G.W' in the issue of 26 May. This quoted a lady of Bembridge Crescent (Southsea) waking up between two and three o'clock on the morning of 19 May 'with a painful sensation of suffocation.' The room was filled with the smell of some noxious gas and 'a lady in Victoria Road also gave me an exactly similar account... It was not a pleasant experience of the comet.' Today, perhaps,

A 20 minute exposure taken with the 75 cm reflector at Khedivial Observatory, Helwan, Egypt captured Halley on 3 June 1910 as it headed back out into the Solar System. (Negative image).

One of the more frequently reproduced pictures of the Comet is this Hale Observatory image produced on 8 May 1910.
Hale Observatories



this would be the signal for an avalanche of letters but only one response to the account from M.G.W. was found during a search of *The Evening News* at this time. One Monckton Hoffe writing from the Queen's Hotel, Southsea reported waking up in the early hours of the same night in a room which 'seemed full of fumes of sulphur' - a room, moreover, that had its windows wide open and looked out over the sea. Hoffe commented on the absence of any mention of the subject in the London press and queried whether the incident had any Earthly explanation. 'I am sure the *Daily Mail* could have made quite a nice column on "The Suffocating Citizen of Southsea".'

The Comet: 'A Fraud'

Scare stories and strange happenings aside, perhaps the most comprehensive and despondent description of Portmouth's experience of Halley's comet in 1910 appeared in *The Evening News* of Thursday 26 May. Under the heading 'Halley's Comet. Disappointed Portsmouth Amateur Observers' the author wrote: 'After much watching and the exercise of the patience of Job, Portsmouth has at last seen the comet... Nothing more than an insignificant starry smudge in the western sky to which those whose enthusiasm was not altogether damped (sic) cheerily added a tail. To those who had seen the Daylight Comet, Halley's was a fraud, a delusion, and a snare...' Quite apart from the indifferent weather, the attempts around this time in May to see Halley's comet would have been impeded by the Moon, which was full on the 23rd (the Moon always makes observing diffuse objects even more difficult).

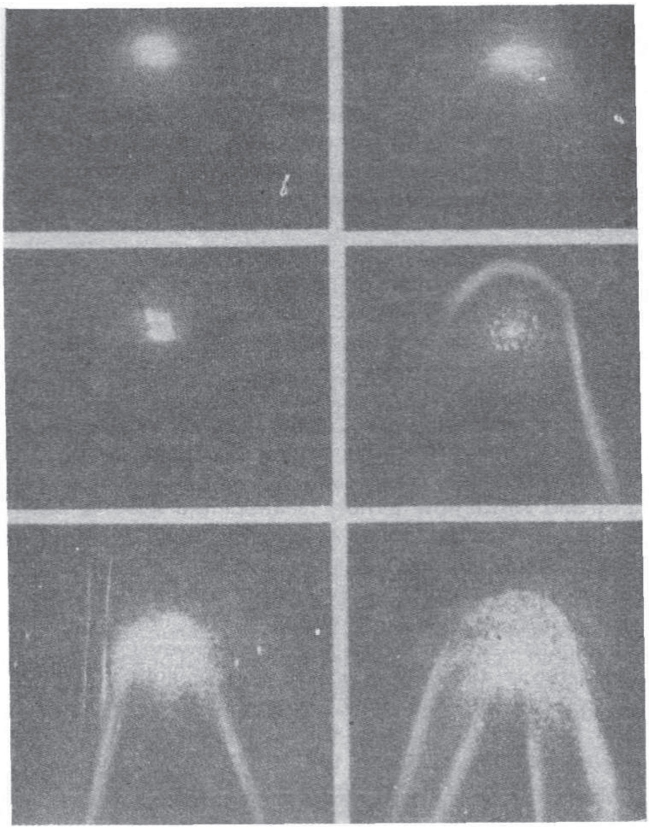
In the same issue, E.W. Maunder of the Greenwich Observatory in a talk to the British Astronomical Association, gave a more balanced and less emotional evaluation. So far as Londoners were concerned he admitted that 'Halley's comet had gained for itself a bad reputation. Most Londoners looked upon it as a distinct fraud but really that was the fault of our positon. Drawings and photographs from other parts of the world showed a far different looking object.'

And that was one of the last mentions of the comet in *The Evening News.* On 3 June a claim by E.S. Grew in the *Graphic* that comets might originate on Earth and that the Krakatoa explosion may have created a small comet, was reported, mercifully without comment. Subsequently there were further reminders of the very unstable weather of the period and a story published on 8 June was headlined 'Thunderstorm Fatalities' and 'Deaths by Lightning.' No doubt some blamed it all on the comet which, so far as the general public was concerned, was now fast disappearing back into the far reaches of the Solar System from which it is now returning.

Conclusions

A number of general conclusions may be drawn from this piece of local research.

1. The coverage by *The Evening News* was extensive, informative and lively. Any person who read the newspaper carefully would have had a good knowledge of the main events of the apparition - but (and this is a reflection on the limited astronomical knowledge of the time rather than a criticism of the newspaper) they would not have gained much of an idea of *what* a comet was. While *The Evening News* coverage in 1910 was in depth and frankly lengthier than may be the case in 1985/6, there was an absence of feature articles presenting a general description and analysis of the apparition. At this time, too, the newspaper reproduced few photographs and there were no images of the comet.



Computer enhancement of two original images (at top: 7 May 1910 left; 8 May right) highlight finer structure. *S. Larson*

2. Quotations attributed to foreign astronomers and (more frequently) to members of the Greenwich Observatory were helpful and were, for example, quick to warn the general public in this country that their sight of Halley's comet would not be as impressive as that of some earlier comets. (It is a sad fact that the prospects for the 1985/6 apparition are even worse.) In addition, a regular and attentive reader would not have confused Halley's comet with the unexpected and earlier Great January Comet.

3. While the skies were occasionally clear and there were some good sightings of Halley's comet, it is evident that generally the weather was poor in the UK at the critical times. Thus, the Portsmouth experience may be regarded as fairly typical of much of the country. This was a major contributory factor to what was obviously the considerable disappointment felt by the general public. This leads to a final conclusion:

4. People still alive today who remember seeing a comet in 1910 or having one pointed out to them would have been, in most cases, between about five and ten years old at that time. It seems certain that most would not have seen Halley's comet but its brilliant and unexpected predecessor.

Acknowledgements

The author would like to thank Ms Pamela Towlson of the Royal Astronomical Society Library; the staff of the local history and newspaper sections of the Central Library, Portsmouth, as well as the staff of the Havant Library; and Mr. A.W. Garrett for their valuable help.

SPACE MEDALLIONS

By L.J. Carter

Coins and medallions have long been used to commemorate historical events. Among those of great historical interest are many concerned with the appearance of comets - formerly regarded as harbingers of pestilence and death. Most are in the hands of museums or private collectors. Nowadays, however, medallions are available at modest cost to commemorate every significant step in the space age. They are of great intrinsic merit and interest and can form the basis for a most intriguing collection.

Coins and Medallions in History

Coins depicting comets were issued in Roman times, struck after the death of Julius Caesar by the Emperor Augustus, Julius' adopted son. There are a number of variants. One shows the head or bust of Julius Caesar with a "hairy star" (the comet of 44 BC) above, the usual representation of a comet in those days. Other Augustinian coins are similar though relating to the appearance of a comet in 17 BC, thought to be a reappearance of the soul of Julius on the occasion of the Saeculer Games (held normally every 110 years) arranged by Augustus, as shown by the herald on the reverse of many of these coins.

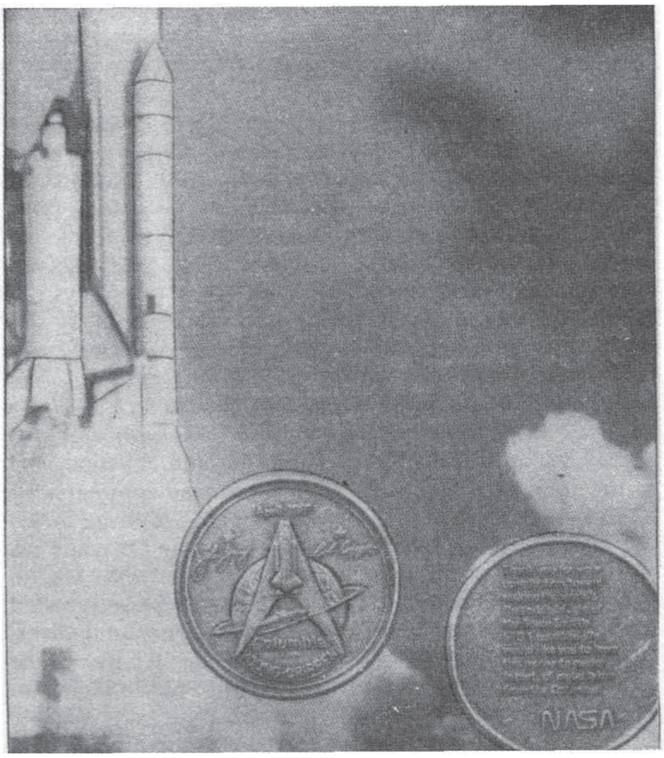
Up to and including the Middle Ages a number of spectacular comets appeared which coincided with dire events on Earth and thus found their way into medallions. For example, the great comet of 1558 "unquestionably announced" the death of the Holy Roman Emperor, Charles V that year, according to contemporary writers e.g. "the death of Charles was foretold by a Comet. At the beginning of his sickness it inclined to the North, at the end it became fixed over the monastery itself and disappeared when Charles was dying."

Stories surrounding medallions concerned with such events make fascinating reading e.g. the Comet of 1664-5 which was seen by Newton and Hevelius. The common people insisted that it was in the form of a fiery sword, pointing to the doomed City of London. It was widely thought to be a Messenger of Divine Wrath. Their worst fears were soon realised. In May 1665 the plague broke out and before long almost every household door bore the long cross and the inscription "Lord have mercy upon us" which told of the plague within. There were no domestic animals left. No dog bayed and no cat walked at night, for 40,000 dogs and 200,000 cats had been killed in the belief that they had conveyed the plague. No infants lived that year. The dead were interred in great trenches with many, no doubt, sharing a like fate though still alive. Out of a population of nearly half a million, at least 100,000 died though, without reliable estimates, it could have reached twice that number.

Scarcely had the plague gone than another terrible disaster befell London. This time it was the Great Fire. The medallion issued in 1666 commemorates this doleful story in depicting a flaming background, dead trees and an air of general desolation.

Recent Comets

With the rapid discovery of more and more comets in the 20th century - but none really spectacular - little has been done to commemorate them. As far as is known, the first medallions commemorating Halley's comet were



A medallion issued by NASA to mark the first flight of the Space Shuttle, 12 April 1981. *NASA*

for its 1910 apparition and were minted mainly in Germany. Several have already appeared in anticipation of its 1986 return and many more will probably emerge. A medallion appeared to commemorate Comet Kohoutek but is now hard to find.

Medallions on general astronomy topics, too, are hard to find though three types of medals, designed by William Andrews, were struck by the Royal Mint in gold, silver and gilt-bronze, respectively, to commemorate the tercentenary of Royal Greenwich Observatory in 1976. These were the only official medals of the tercentenary but there may have been others. The obverse of all three depict Flamsteed House, with reverse designs of an armillary sphere (for astronomy), Harrison (for time) and Ramsden's sextant (for navigation). All are 5½ cm in diameter; the gold medals are 22 carat and weigh approximately 155 g; the sterling silver medals approximately 90 g. Both are hallmarked at Goldsmith's Hall, London. The issue was limited to a maximum of 100 each of the gold set, 1,000 of the silver and 3,000 of the bronze.

Tokens

Further variation took the form not so much of medallions but of tokens or inscriptions. Superstitions, too, had not died out. The wine of the years when a great comet appeared was said to be excellent e.g. the comet 1811 gained further fame on the grounds that its appearance coincided with an unusually good port wine, while the wine in 1858 was also said to be better than that of any others "because of the influence of the comet." The comet, therefore, became a favourite brand or trademark for wines - particularly champagne wines from Europe. Most were impressed upon the bottles themselves but at least one supplier struck a very neat tiny medal to hang around the necks of the bottles.

Strangely, no comets are depicted in any of the wide range of tradesmen's tokens issued in the UK in the 17th, 18th and 19th centuries. Some thousands of designs were created on almost every topic imaginable but the only tokens remotely concerned with an astronomical

topic are those showing Sir Isaac Newton, issued in Cambridge in the 19th century.

Space Medallions

Many medallions have been struck to honour individual contributions to space developments though most have been of a "one off" variety. This category includes, for example, the gold medals awarded by our own Society to Yuri Gagarin, Valentina Tereshkova and all three Apollo 11 astronauts, Neil Armstrong, Edwin Aldrin and Michael Collins. Others have appeared with more general circulation, e.g. the medallion issued to participants at the 1976 IAF Congress. An even higher number of Soviet medallions have been struck honouring Gagarin, Tsiolkovsky and others, though few are available in the West.

Space medallions really came into their own with the advent of the American manned programme. Practically all of the hundreds of different types produced commercially were issued in America. Only a few were produced in the UK but others appeared in France, Spain and Guyana, to name but a few. Members of the Society who visited Cape Kennedy during the Apollo shots were regailed with collections of medallions, both in bronze and silver, depicting all the Mercury and Gemini flights, since extended to include Apollo, Skylab and Shuttle flights to date, including the Spacelab mission.

The commemorative space medallions most easily and inexpensively acquired are those of solid bronze, usually packed in a plastic display case with a simulated velvet background. The normal price is around £2, which puts them well within the pocket of nearly everyone. Practically all are extremely well-designed and suitable to collect, though are probably not subsequently displayed as much as they deserve owing to competition from the more colourful decals (gummed stickers), mission patches, etc.

Even more space-related are a variety of medallions produced by NASA or their contractors for specific space events e.g. the approach and landing tests of Shuttle *Enterprise* in 1977 or coins handed out at anniversary dinners. Those issued by NASA contain many made from alloy mixed with a small part of the structure of the particular spacecraft commemorated, with the result that each medallion, presumably, contains minute specks from the actual craft. Some 200,000 were issued for the Apollo 8 flight; the same for Apollo 11 and more for the ASTP mission.

The Apollo 11 medallions contained metal from both *Eagle* (lunar lander) and *Columbia* (Command Module). Another 100,000 were struck in the case of Skylab, for issue on 14 September 1974, the flown metal being from a camera bracket weighing a little over ½ kg. These medallions were made of aluminium, with a reeded edge. They were 4 cm across and weighed 4.7 grams. For STS-1, 98,000 medallions were struck under a US Government

Medallion to commemorate the 1910 return of Halley's comet depicting the comet's path in the sky and the dates of all known earlier returns (German).

The French mint struck this medal to commemorate the discovery by Jules Janssen and Norman Lockyer of the method of observing solar prominences without waiting for solar eclipses.
(By kind permission of the Cambridge University Press, from Gingerich, 'Astrophysics and Astronomy to 1950').

contract and distributed to all employees on the first Shuttle launch on 12 April 1981. Each medallion contained a particle of metal carried aboard *Columbia's* first flight. A related example was the 25th Anniversary coin given to all NASA employees on 1 October 1983. In the case of dinners, a small piece of ASTP flight material was used in the metal for producing souvenir medallions distributed to 2,000 attendees at an Annual Goddard Memorial Dinner. A National Space Club medallion contained material from Apollo 8, Apollo 11, Skylab, Apollo-Soyuz and even from an early rocket built and flown by the late Dr. Robert H. Goddard. This was a bi-centennial medallion (1776-1976). The front depicts a space helmet, one of Goddard's early rockets and the then projected Space Shuttle. Practically none are on the market at present but, in years to come, a fair proportion will undoubtedly find their way into the hands of dealers from whom they may be purchased.

Coins

Flights to the Moon were also commemorated by an American Silver dollar (actually made of copper and nickel) issued in 1972. This shows a representation of President Eisenhower on the obverse and the Apollo 11 Eagle above the lunar surface on the reverse. 62 million were issued. One of the three dollar coins minted to mark the American bicentennial (1776-1976) also showed President Eisenhower on the front and the Liberty Bell on the reverse but with the Moon also appearing in the background. Versions in both silver and bronze appeared.

Last year the USSR issued a rouble depicting Valentina Tereshkova, the first woman to orbit the Earth. Nearer to home, the Shuttle appears on a crown issued in the Isle of Man in 1983 as part of a set of five to commemorate the bicentenary of Manned Flight.

The 500th Anniversary of Copernicus saw the issue of commemorative coins in Poland and East and West Germany.

[The Society will be interested to receive details of coins or medallions that members come across relating to Halley's comet which appear overseas. Collecting such medallions will prove just as rewarding now as in the past.]

HERMES: THE FRENCH SHUTTLE

By Martin Sénéchal

France intends to press ahead with its Hermes mini-shuttle even if the project does not become part of ESA's programmes. In the light of recent announcements the author looks at competitive studies carried out by Aerospatiale and Dassault-Breguet.

Characteristics

Basic specifications as set by CNES (Centre National d'Etudes Spatiales), the French Space Agency, call for a delta-winged, reusable spaceplane, 15-18 m long with a wingspan of 9-11 m. The weight has to be limited to 13-17 tonnes, imposed by the choice of Ariane 5 as the launch vehicle. The launch weight includes 2.5 tonnes of propellant for orbital insertion, in-orbit manoeuvres and reentry. A payload of 4-5 tonnes could be carried in the payload bay, which has a diameter of about 3 m and a volume of 35 m^3.

Hermes would be used as a service vehicle for space stations, transporting crew and cargo. Missions include the assembly of space structures and scientific and applications experiments. In-orbit maintenance, repair and refurbishment of unmanned satellites and platforms could provide some after-sales service for Ariane-launched vehicles. NASA has repeatedly cited this as a major advantage of the US Shuttle launches over the unmanned Ariane.

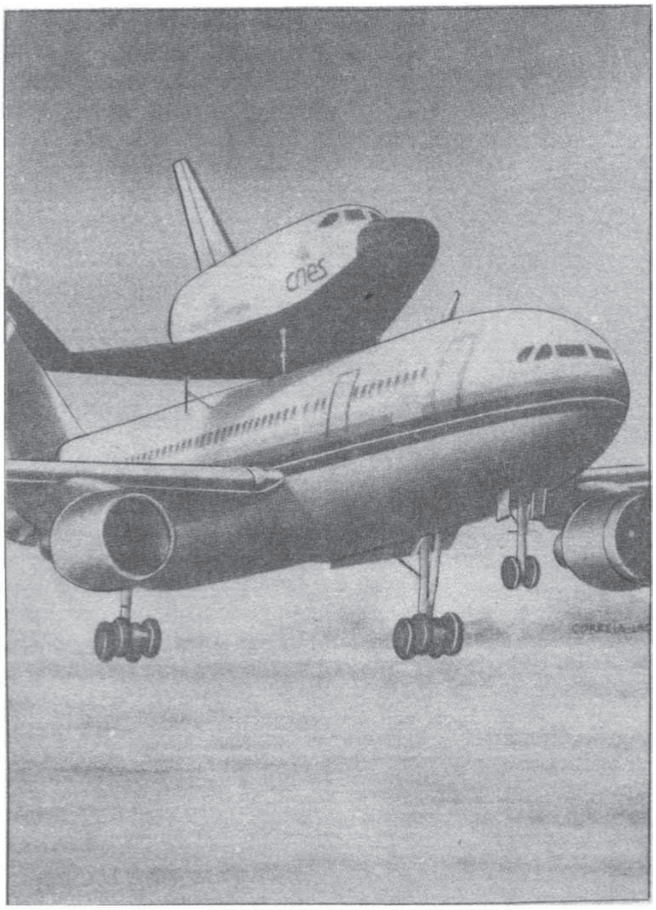
A typical mission would take the craft to a circular 400 km orbit inclined at 0-30° with a crew of two pilots and up to four scientists or engineers. The duration would be eight days but that could be extended to 30 days with a smaller crew, and to 90 days when docked to a space station. Sun-synchronous orbits are also possible at altitudes of 500-800 km with a payload of only 1.5-2.5 tonnes and a crew of 2-4.

Hermes will land on a runway at the Ariane launch site in Kourou, French Guiana, or at a specially-prepared site in Europe. A landing will be possible after only one revolution, even in a near-polar orbit, with a cross-range manoeuvring capability of 2,500 km over a reentry trajectory of 9,000 km. This capability has a considerable effect on the design of Hermes.

Ariane 5

Hermes will be launched atop the expendable Ariane 5, a heavy-lift booster. Development of Ariane 5 was approved during the European Space Agency's Ministerial-level Council meeting in January 1985. The current design focusses on a configuration called Ariane 5P which has a central body with an HM60 large cryogenic engine with two side-mounted strap-on solid boosters. The HM60 is currently under development as a separate ESA programme. Ariane 5P will be developed for launching satellites but will be reliable enough to be man-rated.

Ariane 5P's cryogenic motor and boosters would be ignited on the pad to ensure that the propulsion system is functioning before liftoff. Sea-level thrust of the HM60 is to be 770,400 N, with a thrust at altitude estimated at 1,004,400 N, the engine burning for 500 seconds. The solid boosters would be 19 m long and 3 m in diameter, carrying about 170 tonnes of propellant and burning for approximately 117 seconds. The Ariane would be able to lift a maximum of 13 tonnes into a Sun-synchronous



The Aerospatial Hermes design. *CNES*

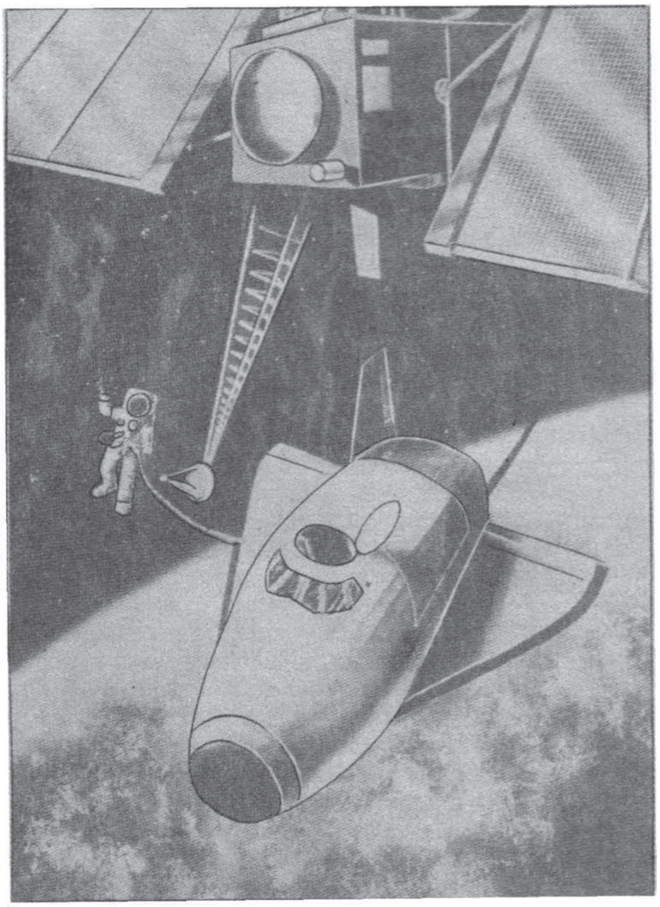
transfer orbit or the Hermes spaceplane into low Earth orbit. The first flight of the rocket is expected during 1994, with operational missions beginning a year later.

The initial flight of Hermes would occur during the second half of the 1990's. Full scale development would start in 1988, enabling the first flight to be conducted during 1997. Intermediate milestones on the CNES calendar include production of demonstration and engineering test models in 1990, followed by systems testing between 1993 and 1996. Development costs through the initial two test flights are estimated at £1,050 million, with £9 million provided for Hermes studies in 1985-86 and £15 million in 1987.

European Cooperation

Since France wants Hermes to become an ESA programme, CNES gave a project-briefing to member states before the top-level ESA meeting in January 1985. Reaction from other members was encouraging and the final resolution of the Ministerial-level meeting states that the French decision to undertake the project, in association with other European nations if possible, was noted with interest. France and her partners were asked to keep ESA informed of the progress made in Hermes studies with a view to including this programme in the Agency's plans as soon as is feasible.

France is determined anyway to continue development and will seek bi-lateral agreements with other European nations if this route is adopted. In 1977, when the SPOT Earth-resources satellite was not accepted as an ESA project, France pressed on alone before being joined by Belgium and Sweden. A number of countries, including Belgium, Sweden and Italy, have already shown interest in CNES' plans and could join France, who would provide 50% of the funding. Other participating countries could enter the programme after CNES has chosen a prime



Hermes in orbit. *CNES*

contractor - a decision expected in the autumn of 1985.

The prime contractorship was the issue of sharply-contested competition between two leading French aerospace companies, Aerospatiale and Dassault-Breguet, with both finishing preliminary studies in March 1985.

The Aerospatiale Proposal

Aerospatiale has used its experience gained from working on missiles and reentry vehicles, the Ariane launcher, communications satellites and civil aircraft such as Concorde and the Airbus series. Their proposed mini-shuttle is 15.5 m long, with a delta wing and small, vertical stabilisers at the wing-tips. Wingspan will be 11 m. A large, centreline vertical stabiliser is located behind the payload bay above the orbital manoeuvring engines. The payload bay has a volume of 35 m^3 and there is a docking/EVA port between the bay and the cockpit area.

Hermes will be an unstable 'plane during most of the reentry and approach stages, when it is slowing down from orbital speed (7 km/sec) to the landing speed of 300 km/hr: Hermes will thus have to be controlled by fly-by-wire under the command of computers and sophisticated software. Here, the work done by Aerospatiale on Concorde (the first transport aircraft with fly-by-wire controls) and the Airbus A-320 (the first with sidestick mini-controllers and fly-by-wire controls) is important.

Sidestick flight controllers are used in the Hermes cockpit, which is clearly inspired by that of the Airbus. One of the two sidesticks controls rotation, while the other commands movement along the three translational axes. The lack of centre-mounted control sticks allows pull-out tables to be installed in front of each pilot. The main instrument panel is fitted with five cathode-ray tubes displaying orbital, navigational and systems data, along with trajectory information required for reentry and landing. The pilots' seats are placed on the forward floor section of the cockpit and are raised to maximum height during the final approach to give sufficient dowards visibility through the windshield. Seats for the remainder of the crew will be located behind the pilots and will have sufficient room between them to add two more seats for astronauts being transferred to or from a space station. These additional seats could be stored on the space station itself or placed under the experimenters' seats when not in use. All seats can be folded out to allow the crew to sleep. Cockpit volume is approximately 26 m^3, which is far more than the minimum requirement set by CNES at 3 m^3 per astronaut. An additional space of 6 m^3 is available under the floor for avionics and life-support equipment.

Propulsion into orbit after Hermes separates from its launcher will be provided by two 20 kN engines mounted in the rear fuselage. Attitude control is provided by a system of eight vernier thrusters on the forward and aft fuselage and these are similar to those already used on Aerospatiale's satellite designs. Dissipation of excess heat from the systems on-board (several kW), the crew (130 W per man) and the variable heating from the Sun will be necessary once orbit is reached. Radiators on the inner side of the payload-bay doors assure the necessary heat loss, circulating cooling fluids through pipes in the radiators.

The cockpit in Aerospatiale's design is an independent, light alloy structure fixed to the interior of the main airframe at four points. This method was dictated by weight and environmental control considerations but also results in less risk of leaks from meteor strikes and gives improved crash protection. Power could be provided by fuel cells, solar panels or thermo-electric generators. All three possibilities are under study.

Experience in thermal protection has been gained by Aerospatiale through its research on carbon materials used as protection for missile reentry vehicles.

The Dassault-Breguet Proposal

Dassault-Breguet has used the expertise acquired from work on its Mirage, Jaguar and Alpha Jet military aircraft and their related avionics and electronics systems. This design bears less resemblance to the American Shuttle than does that of Aerospatiale. It also incorporates a delta wing with modified winglets as vertical stabilisers but has a more slender appearance and there is no large vertical stabiliser in the centre of the rear fuselage.

The crew compartment is equipped with six cathode-ray tube displays, with two touch-screens to facilitate dialogue with the complex on-board systems, and mini-sidestick controllers. The possibility of voice-control of the craft has also been studied.

In 1972-74, the company worked with Grumman on thermal protection for the American firm's Shuttle proposal and produced a system that proved, during tests, to be able to resist around a 100 simulated reentrys at 1,200°C, similar to Hermes' requirements.

Crew safety will be assured by ejection seats, as used in military aircraft; Dassault proposes the system already used in the Falcon 50 prototype. This is usable even at very low altitudes and could, for instance, be used in the case of a failed landing approach.

HERMES UP-DATE

Since this article was written CNES has named Aerospatiale as prime contractor for the programme, with Dassault-Breguet assuming delegate prime contractorship for aeronautics design of Hermes. See *European Rendezvous*, page nine of this issue.

THE INDUSTRIAL SPACE FACILITY

By Dr. Michael Sheehan

The US Space Station will not be operational until the mid-1990's but before the end of this decade a large man-tended space processing platform could be in orbit.

Introduction

On 20 August 1985 NASA opened a new era in the commercial exploitation of space when it signed two agreements with the small Houston-based firm of Space Industries Inc. (SII), which will allow the company to deploy its Industrial Space Facility (ISF) from the Space Shuttle. The ISF is the world's first privately-owned, commercial space platform. NASA Administrator James Beggs declared on signing the agreement that, 'we hope the ISF will be the first of many such platforms to be built by private industry to complement the permanently manned space station and lead, eventually, to an industrial park in space' [1].

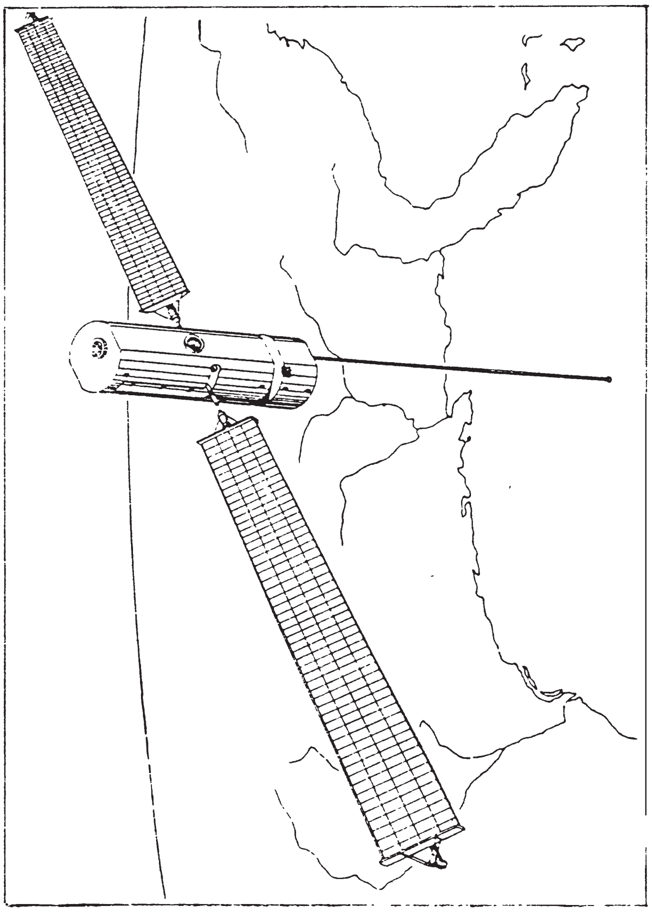
NASA, in fact, seems to have gone out of its way to be helpful to Space Industries. The total cost of the project is likely to be approaching $500 million by the time initial deployment occurs in 1989. That is an enormous financial undertaking for a small, three-year-old company, so some sceptics have raised doubts about its ability to finance the venture. NASA has given the company a considerable helping hand by deferring payment for the 2½ Shuttle missions that will be required to get the facility functioning in orbit. NASA's normal arrangement is to be paid in advance for such launches. The deferred payment arrangement is expected to save Space Industries some $200 million in 'front-end' expenditure. The company will, instead, pay for the flights with the income produced by renting the facility to companies interested in exploiting the commercial potential of near-Earth orbit.

The generous NASA terms appear to be one of the first fruits of the new American policy for the commercial use of space announced by President Reagan in July 1984. The policy was aimed at encouraging and accelerating private sector investment and involvement in space-based business.

Modular Concept

The Industrial Space Facility will be modular in concept and will measure some 10.7 m by 4.4 m. Attached to the facility will be a 3 m supply module capable of being routinely replaced so that products can be returned to Earth and the facility restocked with key expendables. Supply module exchange will be accomplished using the Shuttle's Remote Manipulator System. Visits for facility resupply are currently planned to occur as often as every three to four months.

The ISF is not designed to be permanently manned but rather to provide a habitable environment for astronauts while on-board equipment resupply and servicing is taking place. Shuttle and, eventually, Space Station crews will be able to enter through the Shuttle-ISF docking mechanism or 'berthing adaptor.' Once on board the Facility Module, the astronauts would be operating in a comfortable 'shirt-sleeve' environment while they carried out such tasks as repairs, equipment changeovers, servicing adjustments, the harvesting of completed products and cleaning and restocking of production apparatus. Each



The ISF, a man-tended space processing platform, which could be in operation by the end of the decade.

facility module will have 71 m^3 of pressurised internal volume. Between Shuttle visits, the facility would operate automatically as a 'free-flyer,' though once the Space Station is in operation, one or more facility modules could be attached to it.

The design emphasises ease of maintenance and replacement of parts, as well as updating them over time. The basic modular approach is meant to facilitate this. Wherever possible, the design incorporates proven existing technology and the emphasis throughout is upon simplicity. Most repairs and replacements can be carried out by astronauts from inside the modules but where this is not possible the design facilitates operations by astronauts in pressure suits. Extensive failsafe redundancy is another prominent feature.

This approach of designing the facility around the needs of its users and maintainers is very much the method of Dr. Maxime Faget, the President of SII. Faget has a lifetime's experience of spacecraft design behind him. Between 1962 and 1981 he was responsible for supervising the design, development and testing of NASA's manned spacecraft projects. Officials at NASA feel that if anyone could be said to be the 'father,' in engineering terms, of the Gemini, Apollo and Skylab programmes, it would be him. He is well placed to appreciate the technical and human limitations of the NASA facilities the ISF will depend on and able to design the facility in such a way as to make NASA's job as easy as possible.

Faget has said that he plans to use 1975-class technology for the most part. This use of proven, off-the-shelf technology is a major reason why both NASA and American private industry seem confident that the ISF will succeed. It is not dependent upon future technological breakthroughs but rather is the product of engineers and technology that have already proved themselves in earlier US space projects. Once in orbit, the ISF modules should

be robust enough to remain there almost indefinitely. They are not expected to return to Earth, though this can be done if necessary. In order to maximise servicing efficiency, the first two facilities will be docked side-by-side. The ISF will operate in a circular 230 nautical mile orbit inclined at 28.5°.

ISF and the Space Station

Both Space Industries and NASA envisage the ISF as complementing America's Space Station. The modular approach means that the ISF embodies the capacity for growth in both size and function as business becomes more aware of its potential uses. The facility will be placed into an orbit compatible with that of the Space Station and once the latter becomes operational, probably around the year 1994, the ISF will benefit from operational economies brought about by the frequent Shuttle missions servicing the Space Station. According to Phillip Culbertson, Associate Director for NASA' Space Station office, 'There are characteristics of the ISF and the Space Station that are similar. They both provide habitable work space, are Shuttle-dependent, and essentially autonomous. For these reasons there may be some aspects of the two programmes that are of mutual interest and use to both NASA and SII' [2].

If the ISF is successful, NASA would benefit directly in a number of ways. The NASA-SII agreement gives the Houston company the go-ahead to develop the Shuttle's first docking module. This is primarily designed to enable the Shuttle to dock with the ISF but the same hardware will be available for use as the Space Station's docking mechanism.

NASA will also benefit from the second part of the August 1985 agreement, which provides for a mutually beneficial exchange of information during the definition and preliminary design phase of the Space Station. It is likely that a similar information exchange will be agreed upon for the Space Station development period, scheduled to begin in mid-1987.

A further gain for NASA is that the ISF will be launched four to five years before the Space Station is orbited. The interaction with the ISF will thus provide NASA with valuable operational experience in docking the Shuttle to orbital structures and, more generally, in the basic operations required for manned servicing of permanent orbital facilities.

Potential Uses

The ISF is designed to reach operational status with a single Shuttle launch. Once the first 'facility module' is in orbit, more can be added. When asked how many units SII intend to orbit, Faget commented 'as many as we can sell.' Each facility will have two 30 m solar arrays (similar to those deployed on Shuttle mission 41D) capable of providing up to 12 kW of sustainable power. Other research and production requirements such as cooling and telemetry are also organic to the facility.

Space Industries see their enterprise as essentially a 'real-estate' project catering for prospective space manufacturers. They would provide the environment in which other companies could actually produce. In the words of a company spokesman, 'We provide power, a safe harbour with docking facilities and a base to work in. Our success depends on the aggregate market.' There ought to be no shortage of customers for the ISF. NASA currently has contracts with a large number of companies who use the Shuttle to carry out experiments in space, while the ISF has a number of advantages over the Shuttle in terms of research, development and production facilities. Shuttle flights have an average duration of about a week - a major constraint on the types of experiments that can be usefully carried out in orbit. In contrast, the ISF can run automated experiments for a minimum of three months between Shuttle servicing visits. Moreover, whereas the Shuttle is not designed specifically for such experimentation and therefore possesses limited space capable of being utilised for R&D purposes, as a purpose-built facility virtually all the ISF's 71 m^3 of interior space is devoted to R&D or manufacturing. In addition, manufacturers using the Shuttle must continually launch their hardware into space, whereas ISF payloads remain on station far longer, dramatically reducing the manufacturer's transportation costs.

The advent of the ISF represents a major boon to companies wishing to investigate the potential of space-based manufacturing because it will give them an orbiting facility to operate in even before the Space Station becomes operational. The kinds of manufacturing which the ISF is designed to facilitate include:

- Pharmaceutical products for the treatment of diabetes, emphysema, multiple sclerosis and various blood diseases.
- Pure, exotic crystals for use in high-speed computers.
- New homogenous alloys comprised of mixtures that cannot be produced on Earth because of gravitational effects.

The facilities design also gives it a great deal of versatility. Space Industries argue that it can provide an ideal environment for life-science and material processing experiments, that it is an ideal test-bed for use by US government agencies wishing to develop space-related equipment and procedures and that it can be employed as an 'orbiting warehouse' for R&D equipment, repair parts and logistic supplies [4].

Potential users of the ISF have already been coming forward. A number of American and Japanese companies have expressed a firm interest, while discussions have been held with the European companies involved in the Columbus space station project [5]. The potential for space commercialisation is already being realised. NASA itself has agreements with 20 companies and is negotiating with 24 others interested in the commercial exploitation of space. The first 'made-in-space' products have already gone on sale: polystyrene spheres, each 0.01 mm in diameter and each perfectly round. In July 1985 the US National Bureau of Standards began marketing them as a calibration tool for scientific instruments and as a standard to measure such tiny particles as red blood cells. The NASA-SII agreement represents a major step forward in the utilisation of space. According to NASA Administrator James Beggs, 'One of NASA's top priorities is to expand the economic frontier of space. We view it as a three-pronged effort: working with industry to help identify products that can't be made on Earth; helping business to apply space technology to Earth-based manufacturing techniques; and transferring space-based applications to the private sector. We are beginning to use space to change the stamp of nature on our lives for all time.'

REFERENCES

1. James M. Beggs, Press Statement, 20 August 1985.
2. NASA News, No. 85-119, Washington D.C., 20 August 1985, p.2.
3. *Houston Business Journal,* 26 August 1985.
4. *The Industrial Space Facility,* Space Industries Incorporated, (Houston, 1985), p.1.
5. *Aviation Week and Space Technology,* 2 September 1985, p.26.

SATELLITE DIGEST–188

Robert D. Christy

Continued from the December 1985 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1678 1985-77A, 15997

Launched: 1015, 29 Aug 1985 from Plesetsk by A-2.
Spacecraft data: As Cosmos 1681.
Mission: Photo-reconnaissance, all or part of the payload was an Earth resources package. Recovered after 14 days.
Orbit: 258 x 272 km, 89.88 min, 82.33°.

COSMOS 1679 1985-78A, 15999

Launched: 1140, 29 Aug 1985 from Tyuratam by A-2.
Spacecraft data: As Cosmos 1681.
Mission: Military photo-reconnaissance.
Orbit: 172 x 342 km, 89.67 min, 64.87°, manoeuvrable.

COSMOS 1680 1985-79A, 16011

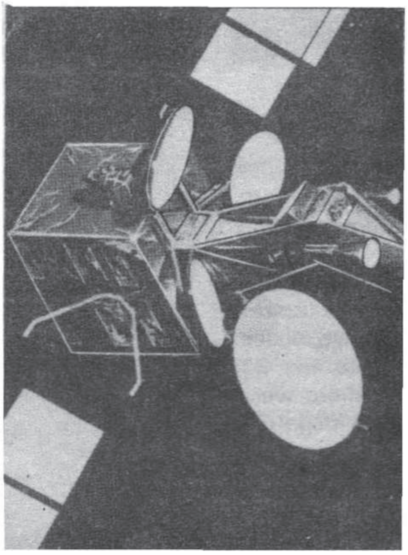
Launched: 0708, 4 Sep 1985 from Plesetsk by C-1.
Spacecraft data: Possibly a cylindrical, solar cell-covered body, 2 m long and 2 m diameter with mass around 700 kg.
Mission: Military communications using a store/dump technique.
Orbit: 784 x 807 km, 100.82 min, 74.06°.

COSMOS 1681 1985-80A, 16018

Launched: 1045, 6 Sep 1985 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft with spherical re-entry module, instrument unit, and a supplementary package of instruments at the forward end. Length 6 m, diameter (max) 2.4 m and mass around 6000 kg.
Mission: Photo-reconnaissance, all or part of the payload was an Earth resources package, recovered after 13 days.
Orbit: 219 x 226 km, 89.02 min, 82.33°.

SOYUZ T-14 1985-81A, 16051

Launched: 1239*, 17 Sep 1985 from Tyuratam by A-2.
Spacecraft data: Near-spherical orbital compartment, conical re-entry module and cylindrical instrument unit with solar panels. Length approx 7.5 m, diameter (max) 2.2 m and mass around 7000 kg.
Mission: Crew and spacecraft exchange for Salyut 7. The three man crew consisted of Vladimir Vasyutin, Georgi Grechko and Aleksandr Volkov. Soyuz T-14 docked with the rear port of Salyut 7 approx 1415, 18 Oct 1985. Grechko returned to Earth with Vladimir Dzanibekhov on 26 Sep (see Updates – below).
Orbit: Initially 196 x 223 km, 88.63 min, 51.62°, then by way of a transfer orbit of 272 x 326 km, 90.45 min, 51.63°, to a docking with Salyut in an orbit of 338 x 353 km, 91.38 min, 51.63°.



Intelsat 5 satellite

COSMOS 1682 1985-82A, 16054

Launched: 0132, 19 Sep 1985 from Tyuratam by F-1.
Spacecraft data: not available but several tonnes mass.
Mission: Electronic reconnaissance over ocean areas.
Orbit: 429 x 443 km, 93.31 min, 65.03°, maintained by a low thrust motor.

COSMOS 1683 1985-83A, 16056

Launched: 1010, 19 Sep 1985 from Plesetsk by A-2.
Spacecraft data: as Cosmos 1681.
Mission: Military photo-reconnaissance, recovered after 15 days.
Orbit: 356 x 414 km, 92.30 min, 72.87°.

COSMOS 1684 9185-84A, 16064

Launched: 0118, 24 Sep 1985 from Plesetsk by A-2-e.
Spacecraft data: Possibly based on the Molniya satellites with a cylindrical body surmounted by a conical motor section with power provided by a 'windmill' of six solar panels, length 4 m, diameter 1.6 m, mass around 2000 kg.
Mission: Missile early warning satellite.
Orbit: Initially 583 x 39334 km, 709.12 min, 62.90°, then raised to 580 x 39762 km, 717.51 min, 62.90° to ensure daily ground track repeats.

COSMOS 1685 1985-85A, 16088

Launched: 1115, 26 Sep 1985 from Plesetsk by A-2.
Spacecraft data: as Cosmos 1681.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 356 x 416 km, 92.31 min, 72.87°.

COSMOS 1686 1985-86A, 16095

Launched: 0842, 27 Sep 1985 from Tyuratam by D-1-E.
Spacecraft data: Cylinder with power provided by two panel solar array. Length 13 m, diameter (max) 4.15 m, and mass around 20 tonnes.
Mission: Carrying of supplies to, and enlargement of, the Salyut 7 station, Cosmos 1686 docked with Salyut's forward hatch at 0916, 2 Oct 1985.
Orbit: Initially 172 x 301 km, 89.18 min, 51.62°, then by way of a transfer orbit of 284 x 318 km, 90.49 min, 51.63° to a docking with Salyut at 336 x 353 km, 91.37 min, 51.63°.

INTELSAT 5A(F-12) 1985-87A, 16101

Launched: 2330, 28 Sep 1985 from Cape Canaveral AFB by Atlas-Centaur.
Spacecraft data: Box-shaped body, 1.66 x 2.10 x 1.77 m with attached 4 m aerial mast and a 15.9 m span solar array. The mass before apogee boost motor firing was 2013 kg, reducing to 1096 kg on total depletion of fuel. The vehicle is three-axis stabilised by momentum wheels and station keeping is by the use of gas thrusters.
Mission: Communications satellite providing the equivalent of 15000 telephone channels at C-band and L-band.
Orbit: geosynchronous.

COSMOS 1687 1985-88A, 16103

Launched: 1923, 30 Sep 1985 from Plesetsk by A-2-e.
Spacecraft data: as Cosmos 1684.
Mission: Missile early warning satellite.
Orbit: Initially 609 x 39194 km, 706.62 min, 62.98°, then raised to 610 x 39732 km, 717.51 min to ensure daily ground track repeats.

COSMOS 1688 1985-89A, 16107

Launched: 0902, 2 Oct 1985 from Kapustin Yar by C-1.
Spacecraft data: not available.
Mission: Possibly a military radar calibration satellite.
Orbit: 347 x 548 km, 93.47 min, 50.68°.

COSMOS 1689 1985-90A, 16110

Launched: 0550, 3 Oct 1985 from Tyuratam by A-1.
Spacecraft data: Cylinder with two, Sun-seeking solar panels, length about 5 m, diameter (max) 2 m and mass around 1500 kg.
Mission: Earth resources remote sensing.
Orbit: 573 x 657 km, 97.06 min, 97.97°.

SPACE STATION MEETING

The Society held its latest Space Station symposium in its HQ Conference Room on 25 September 1985, with a full audience hearing a range of presentations on the theme of "Space Station Applications."

Capt. Robert Freitag, a long-standing Fellow of the Society and Director of NASA's Policy Plans Office (Space Station), described the current status of the US space agency's studies. NASA was 5½ months into the 21 month Phase B (definition) stage and finding there were very difficult decisions still to be made. A major depature from previous programmes was the extensive international element, with ESA, Canada and Japan all making significant contributions. Japan has organised a very efficient industrial team headed by Mitsubishi, Canada was concentrating on the servicing aspect but there was a feeling that Europe was being somewhat slower in producing its detailed requirements and intentions.

Dr. George Peters of ESA described the Columbus programme, indicating that Phase B studies should be completed by early 1987. The deadline for responses to a call for new mission proposals for projects using the Space Station/Columbus was due on 29 November 1985. Columbus will initially be directed at Space Station participation but the eventual goal is to create European space autonomy, possibly based on a free-flying Columbus and the Hermes mini-shuttle.

From the UK point of view, of course, the Space Platform - particularly the polar orbiting aspect - is of considerable interest. Dr. Robert Parkinson of BAe described four platforms under consideration, two co-orbiting with the Space Station and two in polar orbit. The polar versions will be concerned mainly with remote sensing in morning and afternoon orbits, whereas the two co-orbiters have evolved because of the mutually exclusive requirements of astronomical and microgravity payloads. The European far infrared/sub-millimetre telescope (FIRST) is being used to provide a basis for establishing the astronomical platform requirements; its need for frequent slowing would clearly impact the low microgravity condition required by materials processing.

Dr. Don Hardy, of the Royal Aircraft Establishment, discussed the UK's approach to defining user requirements since this will eventually decide the format of the platforms. A core team is heading 13 expert panels on remote sensing, microgravity, astronomical, management and so on, with extensive consultations due to continue until October 1986. A series of open workshps, funded by the government, will be held over the next year to provide a forum for free discussion.

The afternoon session concentrated primarily on applications, with papers considering astronomical, materials research and communications aspects. Dr. Brian Derby of the University of Oxford pointed out that space materials processing, while a highly promising field, was still at an early stage. Of course, the 'g-jitter' produced in the Shuttle, Spacelab and eventually the Space Station by internal movement, demands that materials work must be carried out aboard free-flying craft. Present work is highlighting the feature that removal of Earth gravity allows secondary effects, such as Marangoni convection, to come to the fore. Some features are still poorly understood.

Dr. A.J. Dean of Southampton University provided an excellent example of one discipline that will be propelled forward by the advent of the Space Station: gamma-ray astronomy. By its very nature, this branch of astronomy requires its detectors to be as large as possible and so will be more suited to the main station than smaller free-flyers. In addition, it is not really affected by movement or outgassing by its host.

Claus Toksvig, member of the European Parliament.

As space spokesman for the European Parliament's Committee on Energy, Technology and Research, it gives me great pleasure to send greetings to the British Interplanetary Society.

The European Parliament tries very hard to be a catalyst in all manner of fields. The decision to draw up a report on European Space policy was one of our first major initiatives after the elections in June 1984.

A year's intensive work has resulted in a report to be considered by the Parliament in its October session. The major conclusions are as follows:

1. The French Eureka initiative needs a space centrepiece. We suggest either a permanent Moon base or an autonomous European space station in low Earth orbit.
2. The need for education in the space fields could be met through use of the EEC social fund and through the creation of a European Space Institute which would set the qualifications needed for a European doctorate or MA or BA degree in astronautics.
3. Money should be made available to conduct appropriate studies of space-related data already available to us. In particular, the needs of the Third World in climatology and in mass education should be considered high priorities.

The work on the report has benefitted from close contacts with ESA and others. The need for democratic control in this vital field is stressed. My own hope for the future is that my committee will continue to monitor space developments in Europe and that this early contact with your Society will become closer.

CLAUS TOKSVIG

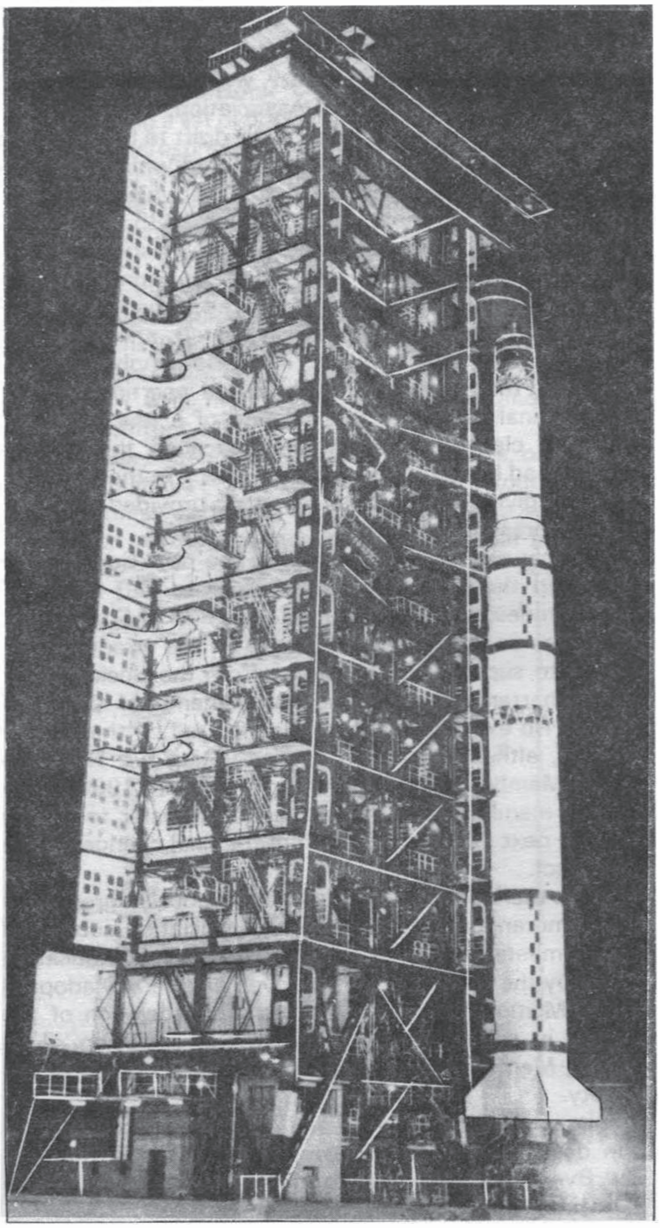
CHINESE SPACE TOUR

Prior to representing the Society at the jointly-sponsored 'Towards Columbus and the Space Station' symposium in West Germany on 3-4 October 1985, Roy Gibson spent two weeks in China at the invitation of the Ministry of Astronautics. After talks with the leading ministry official and those of the technical centre (CAST) in Beijing, he visited aerospace installations in South China, including Kunming not far from the border with Vietnam.

He was impressed by the continued progress being made in the Chinese space programme and, particularly, by the increasing contacts with the aerospace industries and the USA and Western European countries. However, in spite of a cooperative agreement between China and the UK, few signs were to be seen of a British contribution to Chinese space activities.

The visit took place shortly after the Chinese decision to halt the procurement of a direct broadcast satellite system. It was clear that the Chinese authorities were fully aware of the damages of alienating the aerospace industry but there appeared to be substantial reasons for the action, though with reason to expect a resumption of the procurement exercise - in a modified form - in the not-too-distant future.

Chinese launch vehicle.



NASA APPOINTMENT

Richard Barnes, a Fellow of the Society, has been appointed Director of the International Affairs Division of NASA Office of External Relations, after completing four years as NASA European representative based at the American Embassy in Paris. In that capacity he was responsible for liaison with the European Space Agency and the national space agencies of Western Europe on agreed cooperative projects and for identification of potential future joint space projects. He joined the NASA International Programs Office in 1961, serving in various capacities, including Deputy Director of International Affairs before his Paris assignment.

DEATH OF GERHARD ZUCKER

We are sorry to record the death of Gerhard Zucker, an early pioneer of the postal rocket, who died in Duren, Germany, on February 4, 1985, at the age of 76.

Zucker was best-known for his rocket mail experiments carried out between 1933 and 1935, in which he collaborated with a number of BIS members.

He carried out further postal experiments in the years 1956-64 though these attracted little attention.

REPORT OF THE 40TH ANNUAL GENERAL MEETING

The President (Mr. C.R. Turner) welcomed members to the 40th Annual General Meeting by pointing out that, although 1983 marked our 50th Anniversary, this had continued into part of 1984 and one had only to look back on the year to see how much had been accomplished during that time. For example, a wide range of meetings had been held, Society publications maintained at an enhanced level and membership increased by 10%.

Some of these matters would be discussed again later but he wished to express his thanks to the retiring President (Mr. A.T. Lawton), to colleagues on the Council, the Members of Committees and to the Society's staff for all the work that had been done. It was astounding that so much had been achieved in the space of a single year.

The matter of the Society's accounts for the year to 31st December 1984 was introduced by the Executive Secretary who pointed out that, with a successful year behind us in many respects, much was still to be desired on the matter of a satisfactory annual financial surplus for this held the key to our future. It was only by building up surpluses that sufficient funds could be accumulated to enable the Society to undertake the wide range of activities which lay ahead. The accounts disclosed a mixture as before. If one looked at the year itself one could contemplate a very satisfactory period of activity. On the other hand, if one looked to the future, one could see an overwhelming need for even greater effort and greater financial strength if further opportunities were to be grasped.

The report and accounts were agreed unanimously.

The President continued by remarking that, on the matter of Council elections, interest in the work of the Society was undoubtedly reflected by the fact that eight candidates were standing for election. As this was in excess of the four vacancies, the matter would be determined, as usual, by postal ballot. Ballot forms would be

sent to every member of the Society for completion and return by 31st January 1986.

The meeting then proceeded to hear a number of individual reports.

One of the most important and of wide general interest were the arrangements for Space '86, to be held at Brighton on 26-28 September with the theme of 'Space - Profiles of the Future.' Although this represented the third occasion for such a venture, the presentation and arrangements were as exciting as ever. This time the theme had crystalised, almost of its own accord, into papers that presented a continuous thread, beginning with one setting the theme and another that expanded it to the space scene overall, and then continuing with a series reflecting our position poised on the edge of the Universe, looking outwards. The following session was concerned with the input of material i.e. the down-link in information technology and not only on data about the Earth but also about the stars. The question was one of size and enormity, with every sign of it far dwarfing anything we had hitherto experienced.

After contemplating how one could cope with this enhanced flow, two further sessions considered our position in a practical sense i.e. by the construction and utilisation of space stations, including the potential UK involvement, with Europe, and a review of how this might develop. The final session concerned both future means of transportation, including the use of HOTOL, and the problems of living and working in space.

The programme would include a Banquet and Reception, as before, and also a tour of the Royal Pavilion for the Ladies.

Fuller information would appear in both magazines, with registration forms becoming available almost immediately.

Space '86 was only one of a number of fascinating symposia planned for 1986. Another of great importance was the third in our series on the Development and Utilisation of the Space Station, to be held on 21 and 22 May 1986, followed by one on Space Transportation on 19 November 1986. These were additional to the symposia on Soviet Astronautics and Space History, the IAF Congress and the European Space Symposium, among others. In fact, the work involved in making such arrangements had become so continuous as to evoke the description of 'wall to wall Symposia.'

A further matter concerned arrangements for the 1987 IAF Congress. The Society had been involved in detailed arrangements for many years now, for this was a most complicated event requiring substantial funding and considerable organisation. Practically all of the preliminary work had been accomplished and there was every indication that the invitation from the Society to host the International Astronautical Congress for 1987 would be accepted. Fuller details, again, would be published as soon as possible.

The Library had continue to grow, albeit slowly, and give considerable satisfaction to members. The arrangements for combining Library facilities with meetings had worked exceptionally well and produced high praise. The Library Committee, itself, was hard at work in most difficult circumstances, endeavouring to enhance the Library in every possible way. Much of its work, including its frustrations no doubt, were fully reported to members in the pages of our magazines both in the form of Library Reports and From the Secretary's Desk items, as well as in other ways.

One such example of its work concerned the articles that had appeared concerning the Society's unique copy of *Uranometria* which, if all went well, would be offered to members as a facsimile edition. Present plans involved preparing a fully-detailed brochure which would be issued to members shortly to enable them to place orders for advance copies. Those doing so would receive a special discount so this was clearly a useful thing to know. Work on evaluating *Uranometria* was still underway. A computer program had also been secured to enable more detailed studies to be undertaken of the observations themselves. This, it was hoped, would form the basis of a fourth contribution as soon as the work had been done. In the meantime, the articles themselves had proved of considerable interest. Those members who had responded with further comment or additional information may be assured that their interest is greatly appreciated.

Another matter of particular interest and concern to the Society lay in the area of Space Policy. In this field the Society had been particularly active, advocating courses of action and providing technical and similar information on a wide variety of levels. This was something it had undertaken for many years now but which was being accelerated. Members, themselves, could find a valuable supporting role in this work. Letters and articles in newspapers and magazines, both local and national, all helped to create a more favourable space climate. It is important that this work be undertaken as fully, as completely and as energetically as possible. Opportunities are immense, not only to advance UK involvement in space but also to advance the Society itself. Please, however, do not write to the Society itself advocating such matters. The need is to preach to the uncommitted, not to the converted!

The final item of business concerned the Extraordinary Resolution whereby the Society was to adopt a new Memorandum and Articles of Association.

The President pointed out that the draft to be approved was one held and signed by himself and which, in every material respect, was essential to that which appeared in *Spaceflight* for September/October 1985. The slight differences that emerged resulted from misprints (two), the omission of a word or two and the updating of all the sections of the Companies Act referred to because, since our new Constitution had been prepared, another Companies Act had been passed. This was simply a matter of deleting the old section numbers and inserting the new ones. A final item was the deletion of a few words to update a clause in the Articles because the original wording had been superseded by wording in the new Act.

A list giving these changes was provided to each member present for clarity.

The only matter of substance in the new Constitution concerned the introduction of Corporate and Non-Corporate grades, already set out on page 378 of *Spaceflight*. This arose as a direct consequence of the arrangements needed to support an application from the Society for a Royal Charter and meet the requirements of the Privy Council. No existing member was affected by the change because, although election as non-voting (*viz* Non-Corporate) Members would apply from 1 January 1986, every existing member would be eligible to transfer to Fellow over the next 10 years, i.e. before the final changes came into effect.

It was therefore proposed and unanimously agreed that the Memorandum and Articles of Association submitted to the meeting and, for the purposes of identification signed by the President, be approved and hereby adopted as the Memorandum and Articles of Association of the Society in substitution for and to the exclusion of all existing Memorandum and Articles of Association of the Society.

This was put to the vote and carried *nem con*.

In declaring the result, the President added that the new Bye Laws stemming from the changes would also come into effect from 1 January 1986

FROM THE SECRETARY'S DESK

Comet Collectobilia

Finding suitable material for the Society's special collection on comets is becoming harder, with each enquiry invariably bringing the response that the object wished for has already been disposed of. The puzzle is, who *buys* all these things?

Light on the subject was recently shed by G.W. Kronk in his book *Comets*, which disclosed that he had amassed no less than 7000 pamphlets over the last few years. Another example appears in the book *Halley's Comet* by J. Metz, which is almost wholly concerned with describing the collection of an amazing range of items relating to the 1910 return.

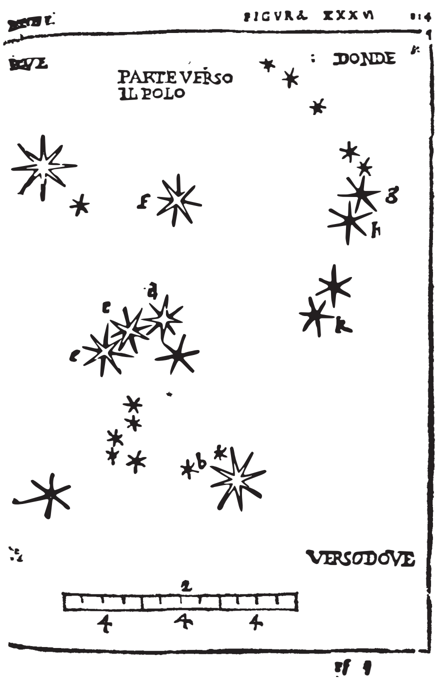
The Chelsea Antiques Fair last September expanded things yet further by listing over 60 items of Comet Jewellery for sale, all collected over the past decade. Apparently such jewellery was worn as amulets or charms, and commemorated not only Halley's comet but others such as Beila in 1846, Donati in 1858, Coggia's of 1874 and the Great Comet of 1881.

Turn-Up for the Book

Examining a list of books for sale the other day disclosed a most interesting volume. It was *De le Stelle Fisse...*, bound with (as is often the case) *Della Sfera del Mondo... (The Sphere of the Universe)* - both by Alessandro Piccolomini and published at the same time.

The first edition (1540) contained the first printed star atlas ever to appear, as opposed to the simplified constellation figures in earlier works. In fact, Piccolomini initiated the use of letters, in his case using consecutive Latin letters, to identify individual stars, a practice later adopted - with modification - by Bayer and so by all modern astronomers.

His book contains 48 woodcut star charts, one for each of the Ptolemaic constellations, depicted in four categories of brightness each with its own scale of degrees and an indication of the direction of the equatorial pole. Since the book was printed in Venice there is every indication that it was probably a most valuable navigational adjunct for the Captains of the Venetian galleys of those days.



But where had I seen it before? A quick mental run-through gave the answer. We already *had* a copy! Ours was a 1561 edition, acquired almost by accident some time ago with the purchase of other items. At that time we were not sure what we had actually obtained but took it 'on spec' in view of its date. Its star charts, prepared without background constellation figures, are very like those that any amateur astronomer might prepare today.

Progress, but in which direction?

Avenging angels have pointed out that *Pilgrim's Progess* was written by John Bunyan and not by John Buchan, as inadvertently stated on p369 of the Sep-Oct 1985 issue of *Spaceflight*. By way of assurance, the error was neither a reincarnation for Lord Tweedsmuir nor cause for John Bunyan to turn in his grave. It was simply an unspotted typesetting mistake.

Referring to the same page Charles Tharratt points out (not for the first time) that his work was only on Black Knight (*not* Black Arrow i.e. the composite craft which included both Black Knight and satellite) as inadvertently stated.

It's true, but Charles deserves the greater glory.

Why do my sins bring instant retribution when those of others are put back, as far as I can see, to Judgement Day?

Society Headquarters

I am frequently asked both by new members and by visitors to talk about our HQ and to explain how we came by it. Interest in the Society and its achievements is most intense but, although this can be satisfied on the spot, those unable to make the journey tend to be overlooked. To rectify this, the following notes provide the gist of what happened.

For many of the prewar years, following its foundation, the Society had no regular HQ at all. It remained an amateur body operated from the private homes of many individuals, not least Arthur C. Clarke who used his 'digs' at 88 Grays Inn Road for Society correspondence and his Somerset address as the 'final frontier,' no doubt to be memorised and then eaten by those members of the Society involved who, hopefully, survived the war and sought to use it as their rallying point when hostilities ceased.

It was effective. Although the Society numbered about 100 Members pre-war, not many of whom reappeared, sufficient emerged to form a solid nucleus on which the Society could be re-formed and re-built.

After a short period, during which it received an exotic accommodation address at Albemarle House, Piccadilly, it reverted to the more mundane address of my own home. There it survived for a number of years, growing rapidly and beginning to take on the shape of a professional body.

After only a few years, it outgrew the capacities of a private home and ventured to find its new offices. These consisted of one (later two) L-shaped rooms at 12 Bessborough Gardens, SW1. At that time the Society was so ill-known that the landlord refused to grant a

lease to the Society but insisted, instead, that it appear in the name of a 'Member of Means.' Subsequently, all went well and the lease was transferred into the Society's name.

From that point the Society continued to grow, based on the labours of one full-time staff member and several volunteer helpers. Fortunately, this occurred during a most fruitful period in the Society's history which saw the establishment of regular lecture programmes and the appearance of *JBIS* as a leading space periodical.

This period, too, saw the extensive groundwork undertaken that led to the foundation of the International Astronautical Federation and its major Congress in London, which set the pattern for future Congresses for many years.

However, the problem of accommodation soon loomed large once more because the Society had continued to grow and its rooms could no longer accommodate its vital paraphanalia which flowed out along the corridors and up the stairs and into every alcove. Accommodation, indeed, became a limiting factor. Not only was more space needed but the problem of ever-increasing rents had to be faced, a position made all the more acute by the fact that we were in an area ripe for development.

As a calculated risk, the Council agreed to surrender the Society's lease and to accept a monthly tenancy on the understanding that no rent increases would be made. This would operate substantially in our favour should development be delayed but be disastrous if early development occurred. In the event, development was held up for some years during which time we stayed at Bessborough Gardens at a purely nominal rent and were thus able to build up a modest surplus against the 'great day' when we would have to move.

Development delays added up to give us a breathing space of four years. Throughout this time we scoured London looking for suitable accommodation, being painfully made aware of three main facts in the process:

1. Even if current rents seemed manageable, there was every chance that these would be increased at regular intervals and the Society's future jeopardised by an ever-increasing commitment.

2. There was no way in which a property could be purchased. For one thing the capital cost was well above any figure we could raise and the interest charges on the balance would represent a cost to the Society even more onerous than the rental.

3. The building we were seeking didn't seem to exist!

As time passed the position became more acute and the Council became more and more concerned about where the solution lay. We were already scouring vacant properties outside the London area when, incredibly and quite fortuitously, a curious thing happened.

Stage I

I normally had to travel through an area that had been largely bulldozed for a road widening scheme at Vauxhall. It lay on the South side of Vauxhall Bridge, just as the Bessborough Gardens address lay on the North side. It was also adjacent to the recently-built Victoria line, with its fast connections to North and Central London, and by Vauxhall Station (British Rail) with frequent connections to the main line stations at Waterloo and Charing Cross.

All that was left of the area, after the road widening scheme, was the old Dalton's Weekly building, a garish construction from the 1920's with a bright yellow and green facade together with the semi-ruins of an adjacent house, vandalised and derelict. The area had actually been bought up by a property speculator with a view to a major redevelopment scheme. Unfortunately, the property boom was just about to collapse, and so did he! I continued my unmolested walks to and from Bessborough Gardens until a sign appeared *en route* indicating that the property was available for purchase.

Enquiries were soon under way and freehold of both properties acquired, though the house, by then, had been listed as a Grade 2 protected building and could only be restored i.e. there was no possibility of flattening the lot and starting again. However, the reinforced framework of the old Dalton's Weekly building was still intact which meant that, at least, some very modest structure could be placed on it on a temporary basis and thus ensure the Society's continued existence. After much heart-searching, perhaps even heart-rending, discussions, the following plan of campaign was agreed:

1. To tackle the building as a ten-year project. Each stage would be divided into a 'module' and added as funds permitted. It would begin with the absolute minimum i.e. just sufficient to provide office space to enable essential activities to continue.

2. At the same time a fund-raising Appeal would be started.

This period, in many ways, turned out to be the most excruciating and yet most productive. The problems of building an office, step by step and, at the same time, running the Society's affairs, which were already almost too large to handle - placed an intolerable burden on staff who, for over two years, had to cram both into their lives, with Society work predominating for most evenings and practially every weekend during the entire period. This was not made easier by a yet further burden, the whole of the preparation and typesetting for the Daedalus Report.

Fortunately, this work brought great rewards. Members became interested in the Trojan work being undertaken and the need to make a 'quantum jump' in the Society's affairs and gave unstinting support. Funds rolled in with Daedalus, too, adding to our coffers. When added to other money-raising plans, the total enabled us to enlarge the single module first envisaged and, as success continued, go the whole hog and have both buildings refurbished and connected together with a new front entrance and thus become a single entity. It wasn't possible for all this to be done on the grand scale of course, but certainly enough to allow us to meet all our objectives on a minimum basis.

Astonishingly, the essential programme was met, and in a space of only two years.

Stage II

Life inside the new HQ building, at first, was very Spartan, with voices echoing, rooms empty and facilities minimal! During the first year of occupation much had to be accomplished in providing much-needed equipment and jettisoning some that had seen better days. Even some carpeting appeared but, before more could be done, the economic ravages of 1980 took their toll. The Society faced a grim prospect. Not only was it £35,000 in debt, representing the money needed for the completion of the building work, but an enormous increase in publication costs had made it impossible for it to run on its normal income.

Severe economies had to be made to match incoming bills, successfully as it turned out while, at the same time, even more effort had to go into trying to whittle down the £35,000 indebtedness. Considerable inroads were made into the problem and by 1981 they were laid to rest when the building was finally paid off.

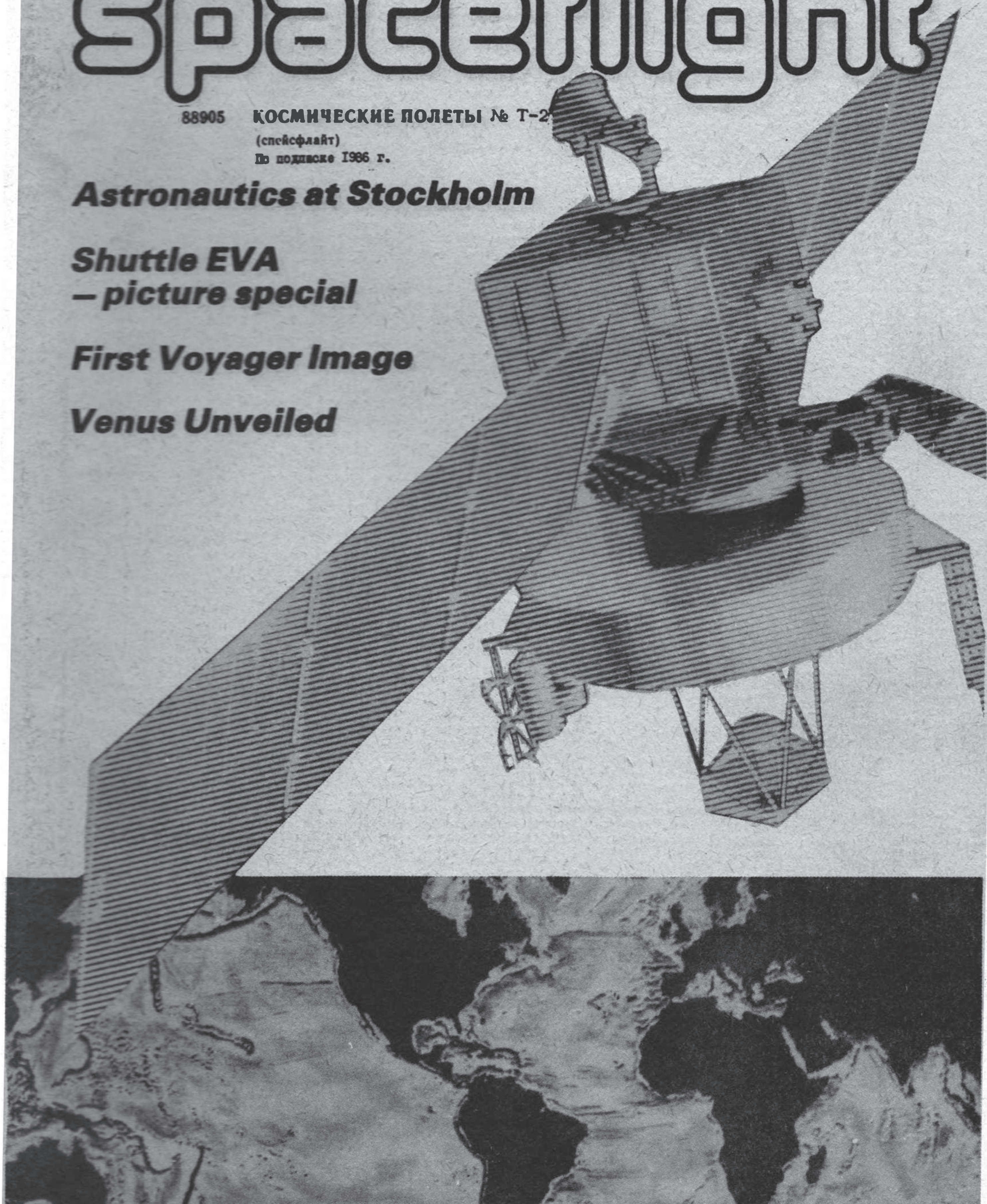
spaceflight

Astronautics at Stockholm

Shuttle EVA – picture special

First Voyager Image

Venus Unveiled

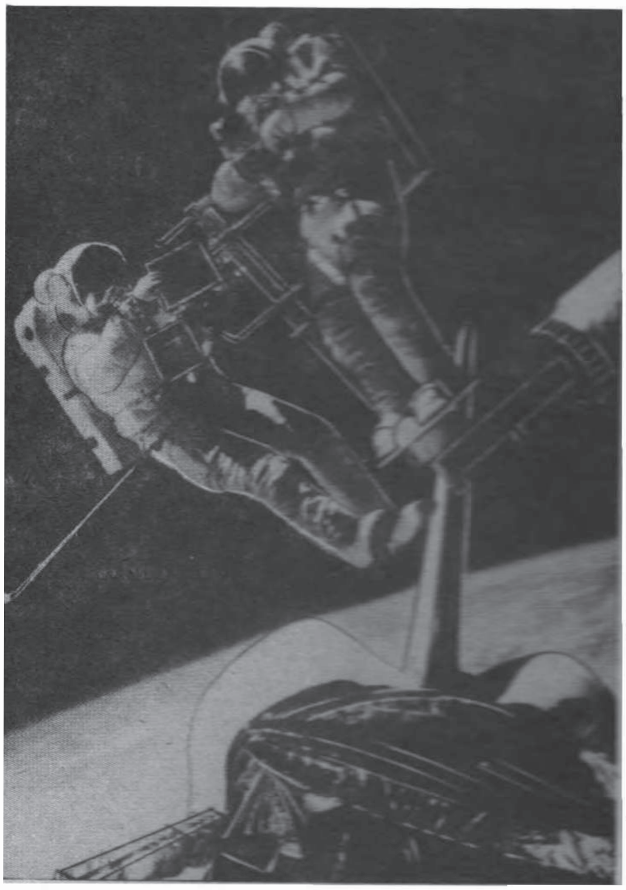


FEBRUARY 1986
VOLUME 28 No. 2

SPACE '86

September 26-28, 1986

PROFILES OF THE FUTURE



A unique opportunity to meet a host of space experts and space scientists from around the world at Britain's premier Space event.

Space '86 is your chance to learn first hand about the space projects of today and the future from those directly involved.

Individual sessions will cover:

Advancing Frontiers

Space Probes

Deep Space Astronomy

The Space Station

Living in Space

APPLY NOW FOR YOUR PLACE AT SPACE '86

The Brighton Centre, set in an attractive seaside location, is the venue for this two-day, weekend conference which includes a Civic Reception and buffet dance, and an evening banquet. For accompanying persons there is the chance to tour Brighton Pavilion and sample the delights of the excellent shopping centre.

To reserve your place at Space '86 write now for a registration form and FREE guide to accommodation in Brighton.

Numbers will be strictly limited to 250 to keep the atmosphere as friendly and intimate as possible, so do no delay, apply now!

Space '86
British Interplanetary Society,
27/29 South Lambeth Road,
London. SW8 1SZ.

ORGANISED BY THE BRITISH INTERPLANETARY SOCIETY

spaceflight

The International Magazine of Space and Astronautics

Editor:
G. V. Groves

Assistant Editor:
C. A. Simpson

Managing Editor:
L. J. Carter

VOL. 28 NO. 2 **FEBRUARY 1986**

CONTENTS

OPPORTUNITY KNOCKS

The Space Station marks a transition between the past and the future. It will go through many phases in development before reaching mature operation but, however daunting the task seems now, in 25 years time we will be wondering what the doubts were about – just as Comsats are now accepted, with very few people remembering the opposition which originally stemmed from vested departmental interests.

An urgent and essential task for our long-overdue National Space Centre is to develop the long-range policy and corporate planning necessary to ensure that the UK secures a seat on the Board concerned with the management of the Space Station. It needs to be involved in its financial control and economic running. Lack of involvement in the actual operation of the Space Station will be to lose out for, in the longer-term, management problems will be paramount.

Technical developments also offer many important opportunities and the UK should be considering, seriously, the scope for more intimate involvement in Space Station technology. For example, a good argument can be made for the need for a pressurised module which could be manned. It might be attached to the Space Station but equally able to be detached if required. It could act as a support vehicle for communications and power systems and enable on-board processing and data handling to be undertaken as well. Another area for technological involvement might be attitude control. There is every indication that this could be refined to provide ultra precise levels of pointing accuracy.

UK involvement in manning of the Space Station should also be under serious consideration. No UK policy and plans for long-term involvement in manned space activities exist to date.

It is important to realise that the four UK astronauts so far selected are in the nature of a one-off quartet. There is no provision for replacement by others nor even are procedures set up to ensure further selections. It is essential that this, at least, be done, if we are to make the best use of our scientists, engineers, military personnel and others who could contribute. Soon, the number of persons entering space will be counted in thousands. Surely the UK will not be content to limit its maximum contribution to four!

Many areas of Space Station operation are in urgent need of evaluation and decision. We urge that an effective organisational structure be developed to undertake these tasks for the UK without delay. The opportunity is there – we must take it and *not* let it pass.

COVER
An Oceanographic research satellite.

IN BUSINESS WITH THE SPACE STATION

The USA has made a commitment to build the Space Station within 10 years to provide a permanent low Earth orbital infrastructure. The most important part of the programme will not start until the hardware is in orbit – after 1992. Europe proposes to support this through its Columbus programme.

The UK has agreed to participate in Columbus by taking the lead in the Space Platform, but providing an element of hardware is not enough – we must become intimately involved in Space Station operations. Planning for that phase starts now. Japan and Canada are also enthusiastic to participate.

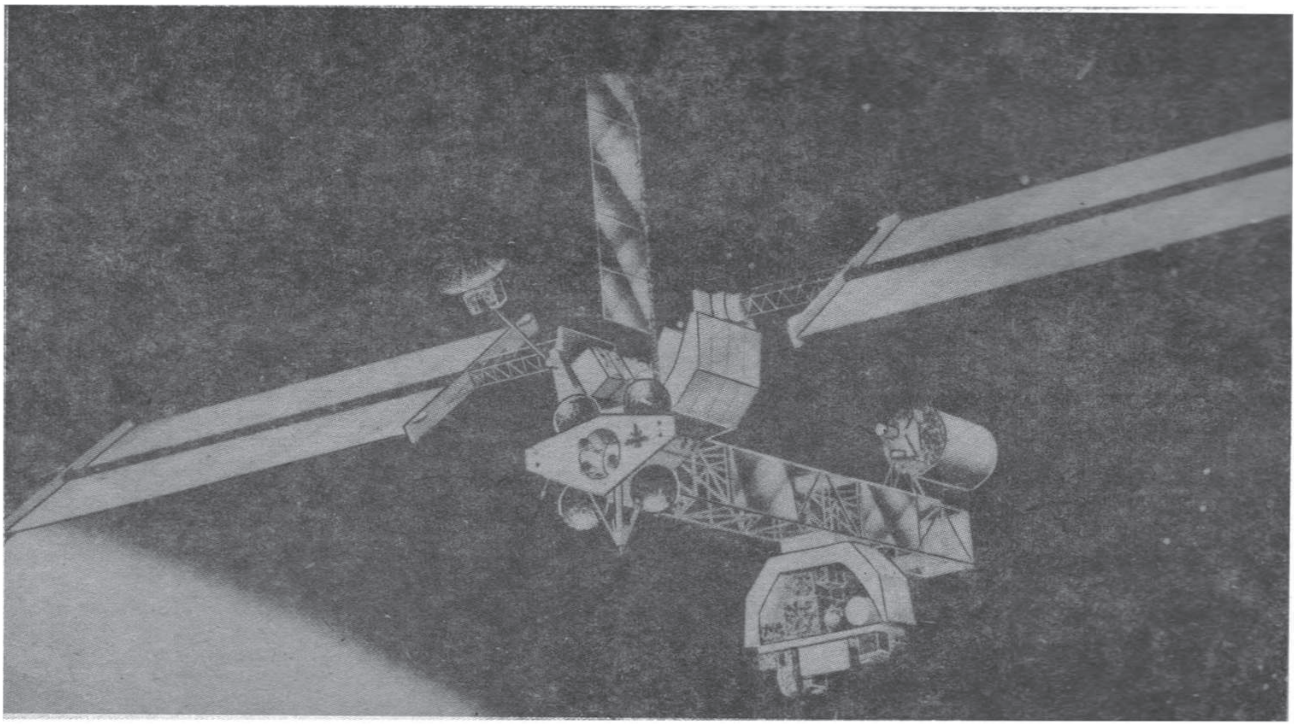
The Space Station will change the way we do business in space. The most important problems are not engineering ones, they are political. Opportunities to exploit space commercially will depend critically on access and cost. The US is already exploiting the Shuttle to encourage new industrial users of space by partnership agreements, which also provides the key developmental factor of allowing users to fly experiments, adjust and fly again. The first industrial astronaut has flown.

The Space Station will greatly extend this capability and provide new facilities for research and production. It will affect traditional areas of space activity and almost certainly become a transport node, checkout and assembly point for geosynchronous satellites. A space based Orbital Transfer Vehicle could undercut Ariane transport costs to GEO or make possible multi-user communications platforms. Similarly, in its Polar Platform facilities (an integral part of the low Earth orbit infrastructure) all Earth observation activities come together. After the Platform there is no more SPOT, ERS, Landsat – simply instruments.

European experience is relevant here, with Spacelab an example of how *not* to co-operate in the Space Station. Simply providing NASA with hardware gives no lasting benefit to Europe. Arianespace is a better example of how the operational phase of the Space Station should be managed. In Arianespace ESA provided the operational hardware but [illegible] allowed an independent organisation to [illegible] planning operations and marketing.

President Kennedy faced a similar situation [illegible] with communications satellites. He forsaw that [illegible] US maintained a monopoly in this area there [illegible] no global users for the system and so [illegible] nations to participate in a communications [illegible] system in the interest of world peace and [illegible] brotherhood among people throughout the [illegible] Intelsat was not officially founded until [illegible] but has been highly successful since and [illegible] encouraged growth in the communications [illegible] business well beyond its bounds. The Space [illegible] illustrates a parallel need for the US to [illegible] integrated management and operations [illegible] international partners. If this is not done there [illegible] strong pressure for Europe, at least, to [illegible] independent, Columbus based, orbital infrastructure [illegible]

A British Aerospace concept for a Space Platform.



President Reagan laid the foundation for an International Space Station Organisation (ISSO) by inviting other nations at the 1984 Economic Summit not only to join in the construction but in the utilisation and operation of the Space Station as a continuing enterprise. The reaction to that invitation, though not immediate, was positive. ESA, Canada and Japan are now involved in decisions being made within NASA about the design characteristics and standards to be used for the Space Station, besides pursuing their own hardward studies. Some of these decisions are far-reaching. The size of the docking hatch on the Space Station will be the size of the docking hatch on the starship *Enterprise,* just as railway guages were set by the size of Stevenson's coal trucks. It is right that these decision be made carefully and with the widest participation.

Equally, the operational management of the Space Station will have wide reaching effects.

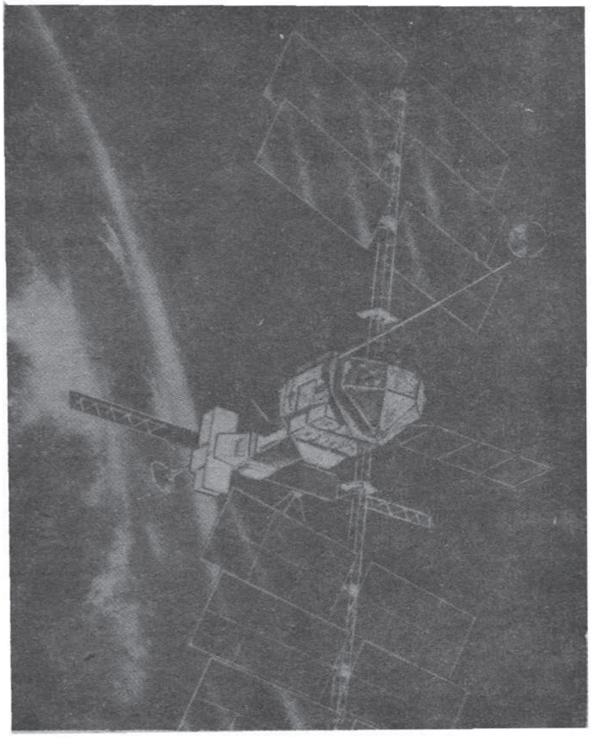
The Space Station management board will be responsible for charging for Space Station services, and hence for deciding who the favoured customers are to be, akin to the partnership agreements already being signed between NASA and 'first users' of the Shuttle facilities. It will be responsible for organisation, scheduling and priorities for Space Station activities, for setting safety and acceptance standards (European users of the Shuttle are beginning to appreciate what a hazard these can be) and for marketing and planning for Space Station growth. It will have to set the basis for future 'Space Traffic Control' systems as well as to ensure financing of the whole operation.

Cracks in the current organisation are beginning to show. One could take the Polar Space Platforms, for example, since that is the area in which the UK has chosen to adopt a main role. Inasfar as these fit into the Space Station infrastructure, NASA would see them under its control. If they are Shuttle-serviced, NASA will need to provide the flights out of Vandenberg to service them. At the same time ESA sees the Space Platforms as part of the Columbus system, under its overall control, and commanded from Germany. Finally, the Earth observation community, under the leadership of NOAA, would like to see an international organisation dedicated to acquiring and processing the dataflow from the Platform and including data relay satellites and archiving facilities but which could operate the Platforms as independent entities.

And this just for the Space Platform, a relatively simple case. Consider the *manned* Space Station if it has a European module, a Japanese module and a Canadian servicing facility. Will it have customs posts at the entry to each? Whose territory will it be? This could be important to some commercial users e.g. US tax laws currently give assistance to high risk investors in such areas but only for spending within the US.

To look a little further forward, assume that NASA decides to develop a space-based OTV while Europe builds a smaller recoverable perigee boost stage which also demands servicing facilities on the Space Station. How will competition between these two systems for transport to GEO be regulated; who will decide what Space Station charges to make – or even whether the fuelling and servicing facility can be installed on the Space Station at all?

Prior to its initial launch, NASA plans to spend $8 billion on the Space Station. European spending will be about $2.5 billion in total. Each party will demand a seat on the Board – in the case of Europe perhaps more than one.



Scientific platforms flying independently of a Space Station are seen as a key specialised area in which British industry could take a leading role.

British Aerospace is the thrust behind this aspect of current UK involvement in the International Space Station project and pictured above is one of the company's concepts for a Polar Orbiting Platform that would form part of ESA's Columbus programme.

Europe has to decide on its strategy for exploiting the operational opportunities provided by the Space Station as quickly as possible. It will mean recognising and accepting that various national interests differ. It will involve starting 'grass roots' movements of users, which does not mean only large companies: new ideas are needed and these also come from individuals. Europe must also consider how to distribute the work on post-1992 Space Station/Columbus operations to meet the geographical distribution of contributions from its member countries, whose contributions will otherwise slacken and die. After this Europe must come to similar arrangements with its other international partners.

Organising an ISSO on such lines will demand compromise on all sides. The US will have to recognise its international partners as full participants in the post-1992 operational phase and be prepared to relinquish control of the Space Station from NASA. Johnson Space Flight Center may find itself a sub-contractor to ISSO. Equally, Europe must compromise and be prepared to separate the operational phase politically and financially, as well as reduce some of its dreams of autonomy.

It is in the interests of all of us to reduce the cost of space operations and to develop new commercial opportunities as rapidly as possible even if, in some areas, this is best achieved by competition. The Space Station infrastructure is on such a scale that it has to require the closest collaboration among all the participating nations, perhaps even leading to a new international organisation with all the political complications that implies. Consideration about this ought to start now.

THE SHAPE OF THINGS TO COME

By Clive Simpson

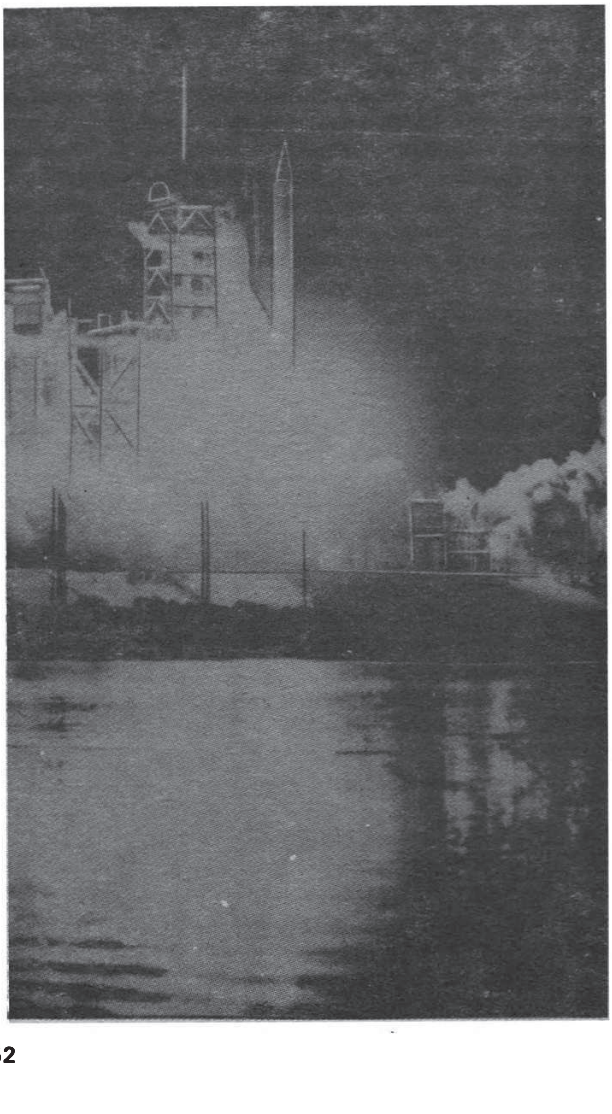
The mechanism of building a Space Station in orbit came into sharp focus during the flawless performance of the Atlantis crew in demonstrating for the first time construction techniques in space.

Highlights of Space Shuttle mission 61B, the second for Atlantis, were two lengthy spacewalks by astronauts Sherwood Spring and Jerry Ross to test construction techniques that will be needed to build a permanently manned Space Station in the 1990's.

The two astronauts spent a total of more than 11 hours in space to build a 3.5 m high aluminium tower and a 3.6 m pyramid above the Shuttle's open payload bay.

Spectacular television pictures showed Spring manoeuvring the 120 kg metal tower through space like a weightlifter toying with a metal framework many times his size.

Night-time lift-off for Atlantis.



During the two EVA's the astronauts assembled and took down the large space structures several times, moving the various parts about easily by hand in the weightless environment.

Among the tasks undertaken by Spring and Ross were:

- Large structure assembly – building and taking apart a 45 foot tower twice and assembling and dismantling a large pyramid structure eight times.
- Utility installation – Ross attached a simulated electric cable along the tower as astronaut Mary Cleave precisely guided him from inside the Shuttle atop the manipulator arm.
- Positioning – both astronauts were able to move and keep the large structures under control and position them accurately for insertion into simulated Space Station structures.

The mission's first EVA was devoted to gathering data on space assembly tasks and the relationships to similar tasks undertaken during water tank training. Times compared favourably, with 55 minutes being taken to construct the tower in space compared to an average of 58 minutes in the water tanks. The actual time allocated on the mission was two hours.

Both Ross and Spring were in fixed work positions for the tower assembly, but the pyramid structure was designed to evaluate free climbing construction.

Ross first put in place two riser beams each with one end attached to the pallet in the Shuttle's cargo bay, and then both he and Spring climbed up the poles to connect a top crossbeam.

The astronauts gained enough time to do eight 'buildups' of the pyramid instead of the originally planned six.

The second EVA involved more specific space facility tasks and had the added dimension of using the Shuttle's manipulator arm for assembly.

First the astronauts built up nine of the tower's 10 bays from fixed work positions on the pallet. Ross then climbed onto the arm so that Cleave, from inside the Orbiter, could elevate him to the top of the structure.

After completing construction of the upper (tenth) bay Ross strung a simulated electric cable up the side of the tower, again guided expertly on the manipulator arm by Cleave.

Later, Spring released the tower from its support enabling Ross to manoeuvre the entire structure with his hands before lowering it back precisely into the assembly jig.

Spring then moved onto the arm and practised various aspects of structure repair, disassembling the top bay and performing a simulated repair of the eighth.

The pyramid structure was again assembled by the two astronauts, this time with Spring on the arm, rather than floating freely, to simulate assembly of

FOURTH SHUTTLE IS THE LIGHTEST

On October 3, 1985 the Space Shuttle Atlantis left launch pad 39A of the Kennedy Spaceflight Center on its maiden voyage. It was the only Shuttle to have made its first flight on schedule, ***writes Roelof L. Shuiling.***

Shuttle mission 51-J, a classified Department of Defense mission, landed at Edwards Air Force Base in California four days later on October 7.

Atlantis is the fourth, and currently last, Shuttle to enter NASA's fleet. It is lighter than Columbia, Challenger, and Discovery but is similar to Discovery in being capable of safely sustaining higher heat and structural loads during launch and landing. Atlantis and Discovery are also strengthened in order to be flown from the Vandenberg Air Force Base in California.

A launch from Vandenberg requires a north to south course to avoid flying over populated areas and to put the Shuttle in a high inclination orbit. Such an ascent trajectory loses the advantage of the Earth's rotation present in a west to east launch from Kennedy Spaceflight Center.

A greater amount of energy is required to reach the 65 to 105 degree inclination orbits flown from the California site and more propellant and greater thrust levels are needed with a resultant demand for more structural strength.

As with Discovery, Atlantis' upper wings and fuselage are coated with Advanced Flexible Reuseable Surface Insulation (AFRSI), a quilt-like insulation used in place of the low temperature white tiles used on the first two Space Shuttles. This advanced insulation is also used on Atlantis' payload bay doors and vertical stabiliser.

Atlantis, like Challenger, has been equipped with the fluid lines, wiring, and cryogenic assemblies which are required to carry the Centaur upper stage for the launching of planetary spacecraft. Umbilicals are provided for loading and venting liquid oxygen and hydrogen.

Graphite epoxy has replaced some internal aluminum structural members and Atlantis, at 169,680 pounds dry weight, is 177 pounds lighter than Discovery. Challenger weighs 170,868 pounds and Columbia is the heaviest Shuttle at 176,361 pounds.

Mission commander for 51-J was Karol J. Bobko, who had previously flown on the STS-6 flight, pilot was Ronald J. Grabe and mission specialists were David C. Hilmers and Robert L. Stewart. Stewart had previously flown on the STS-8 mission in February 1984. William A. Pailes, an Air Force Spaceflight Engineer, was the fifth crewman.

large individual station parts from a moving platform.

The two EVA's lasted five hours 30 minutes and six hours five minutes respectively and after each both Ross and Spring said they were "fatiqued", adding that their hands felt stiff and numb following the construction and disassembly of the space structures.

During the first three days of this Shuttle mission the crew successfully deployed three communications satellites for the Mexican and Australian govenments, and another to serve customers of RCA American Communications Incorporated. The RCA Satcom K-2 satellite became the first satellite ever to be launched without insurance coverage.

McDonnell Douglas engineer Charles Walker made his third trip on the Shuttle and his duties included the monitoring of the latest in a series of experiments for purifying pharmaceutical products in a gravity-free environment. The process, known as continuous flow electrophoresis, was used to purify a batch of synthetic human hormone that could one day treat millions suffering from certain forms of anemia.

Another commercial experiment aboard Atlantis, sponsored by the 3M Company, was designed to produce pure organic crystals that can be used for optical switches and in computers that process information with light instead of electricity.

The astronauts also used special high-resolution cameras to search for geologic signs of surface and underground water supplies in drought-stricken Ethiopia and Somalia.

Atlantis had made a spectacular start to its second mission on November 26 with only the second night-time launch of the programme.

The Orbiter landed on a concrete runway at Edwards Airforce Base – due to a rain-soaked lakebed – on December 3 after a mission that was hailed by NASA as one of the most successful ever.

COUNTDOWN HALTED

Space Shuttle Columbia suffered a late set back on its second attempt to get into orbit for a pre-Christmas mission.

The launch, originally scheduled for December 18, was first postponed for 24 hours after final systems checks fell behind schedule.

A day later it was called off just 14 seconds before lift-off due to problems with one of the two solid rocket boosters. NASA officials said the booster had exceeded the "red line" (high temperature safety line) causing the main computer to shut off the countdown just before ignition.

Columbia, the first of the US Space Shuttle fleet, had not flown in space since November 1983. The Orbiter has been at Rockwell International in California for hundreds of modifications.

MORE POWER FOR SHUTTLE

Heavier payloads will be carried into orbit by the Space Shuttle in the future as a result of refined main engines which are generating more thrust, ***writes Nicholas Steggall.***

Following a series of acceptance tests for the 18th flight engine in the Shuttle programme power levels will be set at 109 per cent.

Previously all flight engines were acceptance tested at the 100 per cent and then 104 per cent power levels. The increase in thrust will enable heavier payloads to be carried.

At the 109 per acent power level each engine produces 417,300 lb of thrust at sea level which amounts to a 42,300 lb increase over the 100 per cent power level.

Spectacular Mission 61B EVA Pictures – See Centre Pages

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

CHANGES AT NASA

The new acting administrator at NASA, William Graham, has appointed Phil Culbertson as general manager with John Hodge succeeding Culbertson in the post of associate administrator for the Space Station and Robert Freitag moving up to deputy associate administrator.

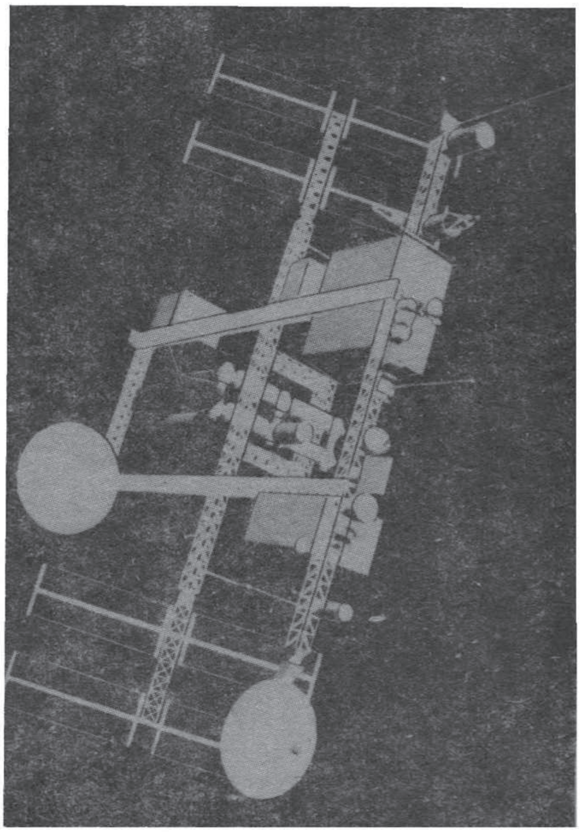
LATEST DESIGN HAS TWIN KEEL

A new reference design for the international Space Station has been drawn up by NASA in response to suggestions from potential users.

Its aim is to provide a more stable microgravity platform for materials processing and increase the available structure on which telescopes and other scientific instruments can be mounted.

The concept (pictured above) has a 'dual keel', box-like design and is retangular in shape, measuring 300 feet by 140 feet. Laboratory and habitable modules would be in the centre of the structure, near the station's centre of gravity.

NASA is expected to announce its choice of a final base-line reference configuration for the Space Station before the end of March 1986.



CANADA TO MONITOR ICE FLOES

A Canadian satellite designed to protect shipping and oil exploration platforms in and around the Arctic from ice floes has been scheduled to fly in 1991.

Radarsat, with a multiple beam synthetic aperture radar, is designed to provide 24 hour coverage and will be deployed from the Space Shuttle's payload bay by Canada's manipulator arm before transfer into a Sun-synchronous polar orbit at an altitude of 1,000 km.

DOUBLE TIME FOR SHUTTLE CREW

Astronauts will now get a double dose of Comet Halley during the Space Shuttle's Astro mission in March.

Extra time for observing the comet has been gained by moving a commercial satellite payload to a different flight.

Westar 6, booked on the Astro mission, demanded a tight launch window which would have inadvertently limited Halley viewing time to between three and five minutes per orbit.

Now the astronauts and crew will be able to spend up to 10 minutes at a time observing Halley after Western Union agreed to transfer Westar 6 to mission 61-H in late June.

Observations of Halley will be made using large telescopes mounted on the Dornier Instrument Pointing System. NASA officials hope that difficulties with the pointing system during the early part of the Spacelab 2 mission will not be repeated.

INDIA'S THREE-IN-ONE SATELLITE

A new Insat-1 series multi-purpose satellite has been ordered from Ford Aerospace by the Indian Government, ***writes Nicholas Steggall.***

This satellite Insat-1D, will provide India with long-distance domestic telecommunications, meteorological Earth observations and data relay, together with nationwide direct satellite television broadcasting. No other satellite in orbit performs all three functions.

The Insat-1 system is the most cost effective solution to providing these three applications requirements over the rugged terrain and inaccessible regions of India. The cost of running landlines into thousands of towns and villages would be prohibitive.

Improvements to Insat-1D give it a larger propulsion tank to provide a longer life in space and an additional redundant Travelling Wave Tube Amplifier (TWTA), plus a larger battery to allow the satellite to operate its communications system during the two annual eclipse seasons.

Insat-1A was launched in 1982, Insat-1B in 1983 and

Insat-1C is to be launched by the Space Shuttle later this year. A date for the fourth satellite in the series has not been fixed.

NASA SETS SPACE TUG TARGET

Design proposals for a 'space tug' are being considered by NASA and a contract is due to be awarded for development and manufacture in June 1986.

Competition to build an Orbital Manoeuvring Vehicle (OMV), which would be used to help build the Space Station and transfer satellites and other objects between Earth orbits, is between three American companies, LTV, Martin Marietta and TRW.

The companies had until December 20 to submit details and from their proposals NASA will select one to build the vehicle, with a target of early 1991 for the first flight.

The contract will include provisions for testing and hardware flight testing prior to actual operational missions. One manoeuvering vehicle will be built with an option by NASA to build a second.

The vehicle would be an element of the present Space Transportation System, the heart of which is the Space Shuttle. Although the Shuttle has already proved an effective ferrying system in moving satellites and other equipment to space and back, the range-extending capabilities of the manoeuvering vehicle make it a valuable addition to the Space Transportation System. It would extend the reach of the Shuttle by 1,000 miles.

The OMV would have the ability to retrieve satellites from high orbits, bring them back to the Shuttle for maintenance and repair, then return the repaired satellites to their operational orbits. It also would serve as a means of reboosting satellites as their orbits gradually decayed.

The manoeuvering vehicle will be an unmanned spacecraft, 15 feet in diameter and approximately four feet in length. Its life will be approximately 10 years with refurbishment and on-orbit maintenance included in the design.

AUTOMATIC LOADING SYSTEM

A system using artificial intelligence to load liquid oxygen into the Space Shuttle external tank prior to launch is being tested at the Kennedy Space Center Advanced Project Office.

The experimental Liquid Oxygen Expert System (LES) is designed to detect and locate faults by processing data from hundreds of system sensors and determine if the fault necessitates halting the countdown – a task which is currently carried out by engineers.

MILESTONES

November 1985

6 Shuttle Challenger landed at Edwards Airforce Base after a successful Spacelab D1 flight, the fourth mission of the European-built space laboratory.

10 Voyager 2 detected one of Uranus's thin, dark rings during the "observatory" phase of its mission. Ground observations determined it to be the thickest and densest of the giant planet's nine known rings.

18 A cold flow test in Centaur stage support equipment failed but NASA officials said it would not jeopordise the Shuttle Centaur programme.

20 The first Director-General of the British National Space Centre, Mr. Roy Gibson, was appointed. Mr. Gibson is a former director-general of the European Space Agency.

21 Soviet cosmonauts were unexpectedly returned to Earth from the Salyut 7 space station due to the illness of commander Vladimir Vasyutin. This was the first time any space mission, Soviet or American, had to be terminated because a crew member fell seriously ill.

27 Shuttle Atlantis lit up the night skies of Florida with only the second ever night-time launch of a Shuttle. The change from a day launch was due to new deployment requirements for the Mexican communications satellite carried by the mission.

28 Voyager 2 returns the first clear pictures from Uranus prior to its encounter still eight weeks away.

December 1985

1 Atlantis crew carry out the second of two lengthy spacewalks during which they test construction techniques on simulated Space Station structures.

3 NASA announces that future Shuttle landings will be at the Kennedy Space Center after the successful return to Earth of Atlantis using the concrete runway at Edwards Airforce Base, California.

10 Arianespace signs contracts with the European Space Agency for the launch of ECS 4 (scheduled for the second quarter of 1986) and Hipparcos (June 1988).

Please note that some of the dates quoted above refer to the announcements of the events and not necessarily to the events themselves.

HALLEY'S COMET MISSION ENCOUNTERS

Project	Agency	Launch date	Flyby date	Distance (km)
Vega 1	Intercosmos	15 December 1984	6 March 1986	10,000
Vega 2	Intercosmos	21 December 1984	9 March 1986	10,000
Sakigake	ISAS	8 January 1985	11 March 1986	7 Mill.
Planet A	ISAS	19 August 1985	8 March 1986	200,000
Giotto	ESA	2 July 1985	13 March 1986	500
ICE	NASA	22 December 1983	28 March 1986	32 mill.

INTERNATIONAL SPACE REPORT

SATELLITE DIGEST - 189

Robert D. Christy

Continued from the January issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

MOLNIYA-3 (26), 1985-91A, 16112

Launched: 0728, 3 Oct 1985 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with conical motor section at one end, deriving power from a 'windmill' of six solar panels. Length 4 m, diameter 1.6 m, and mass around 2000 kg.
Mission: Communications satellite providing telephone, telegraph and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially 623 x 40592 km, 734.29 min, 62.80 deg, then lowered to 614 x 39786 km, 718.70 min, 62.85 deg to ensure daily ground track repeats.

STS-51J, 1985-92A, 16115

Launched: 1515*, 3 Oct 1985 from the Kennedy Space Centre.
Spacecraft data: Shuttle orbiter 'Atlantis' on its first flight.
Mission: All military crew of Bobko, Grabe, Hilmers, Stewart and Pailes, with the primary mission of launching two communications satellites. 'Atlantis' landed at Edwards AFB on 7 Oct.
Orbit: 476 x 515 km, 94.34 min, 28.52 deg.

USA 11, 1985-92B, 16116

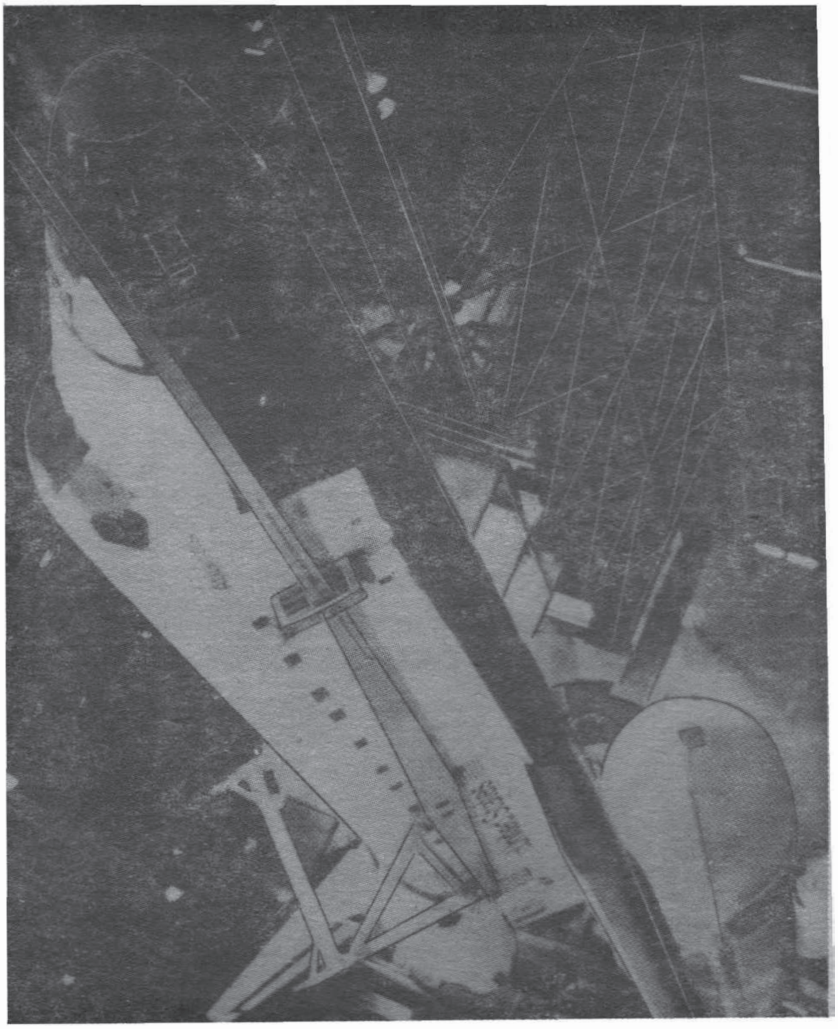
Launched: 4 October from the payload bay of 'Atlantis', using an IUS.
Spacecraft data: Three axis stabilised, possibly an irregular box around 2 m x 2 m x 2 m with solar and aerial arrays. The mass is around 1000 kg.
Mission: DSCS-3 (Defense Satellite Communications System) satellite for US military communications.
Orbit: Geosynchronous.

USA 12, 1985-92C, 16117

Launched: 4 October from the payload bay of 'Atlantis', using the same IUS as USA 11.
Spacecraft data: Three axis stabilised, possibly an irregular box around 2 m x 2 m x 2 m with solar and aerial arrays. The mass is around 1000 kg.
Mission DSCS-3 satellite for US military communications.
Orbit: Geosynchronous.

USA 10, 1985-93A, 16129

Launched: 0258, 9 Oct 1985 from Vandenberg AFB by Atlas E.



Orbiter Atlantis is gently lowered into place next to the external tank and solid rocket boosters in the Vehicle Assembly Building prior to its first mission on October 3, 1985, during which it deployed two military satellites.

Spacecraft data:. Box shaped body, approx 2 m on each side with two solar panels, mass around 800 kg.
Mission: 'Navstar' type navigation satellite within the Global Positioning System (GPS).

COSMOS 1690-95, 1985-94A-F, 16138-16143

Launched: 2140, 9 Oct 1985 from Plesetsk by F vehicle.
Spacecraft data: not available
Mission: Possibly short range, tactical communications satellites.
Orbit: 1389 x 1417 km, 113.91 min, 82.61 deg (lowest): 1413 x 1417 km, 114.16 min, 82.63 deg (highest)

COSMOS 1696, 1985-95A, 16169

Launched: 0925, 16 Oct 1985 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft with spherical re-entry module, instrument unit and a supplementary package of instruments at the forward end. Length about 6 m,

diameter (max) 2.4 m and mass around 6000 kg.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 230 x 281 km, 89.65 min, 70.39 deg.

CHINA 17, 1985-96A,. 16177

Launched: 0500, 21 Oct 1985 from Shuang Cheng Tse by CZ-2 (Long March 2).
Spacecraft data: Possibly cylindrical, with a hemispherical recoverable capsule at one end, about 3 m long, 2 m diameter, mass around 2500 kg.
Mission: Photography – either military or Earth resources, the capsule was recovered after 5 days.
Orbit: 171 x 393 km, 90.19 min, 62.98 deg.

COSMOS 1697 1985-97A, 16181

Launched: 0705, 23 Oct 1985 from Tyuratam, launch vehicle may be new type.
Spacecraft data: not available.
Mission: Possibly electronic intelligence gathering, the orbit is similar to Cosmos 1603 and Cosmos 1656 (both D-1-e launches).
Orbit 849 x 854 km, 102.00 min, 71.00 deg.

COSMOS 1698, 1985-98A, 16183

Launched 2024, 22 October 1985 from Plesetsk by A-2-e.
Spacecraft data: Possibly similar to Molniya-3 (26).
Mission: Missile early warning satellite.
Orbit: Initially 601 x 39434 km, 711.31 min, 62.93 deg; then raised to 603 x 39725 km, 717.24 min, 62.95 deg to ensure daily ground tract repeats.

MOLNIYA-1 (65), 1985-99A, 16187

Launched: 0042, 23 Oct 1985 from Tyuratam by A-2-e.
Spacecraft data: similar to Molniya-3 (26).
Mission: Communications satellite providing telephone, telegraph and television links through the 'Orbita' system.
Orbit: Initially 633 x 38849 km, 700.17 min, 62.97 deg; then raised to 631 x 39731 km, 717.91 min, 62.97 deg to ensure daily ground track repeats.

METEOR 3 (1), 1985-100A, 16191

Launched: 0230, 24 Oct 1985 from Plesetsk by F vehicle.
Spacecraft data: Probably similar to the Meteor 2 vehicle, a cylinder with two, sun-seeking solar panels. Length about 5 m, diameter 1.5 m and mass around 2200 kg.
Mission: Meteorological satellite returning scanning radiometer and other remote sensing data on the Earth's resources and cloud cover.
Orbit: 1217 x 1251 km, 110.33 min, 82.56 deg.

COSMOS 1699, 1985-101A, 16198

Launched: 1440, 25 Oct 1985 from Plesetsk by A-2.
Spacecraft data: Probably similar to Cosmos 1696.
Mission: Military photo-reconnaissance.
Orbit: 168 x 338 km, 89.59 min, 67.15 deg, manoeuvrable.

COSMOS 1700, 1985-102A, 16199

Launched: 1545, 25 Oct 1985 from Tyuratam by D-1-e.
Spacecraft data: Possibly a cylinder with two solar panels and an aerial array at one end. Length 5 m, diameter 2 m and mass around 2000 kg.
Mission: Experimental communications satellites.
Orbit: Geosynchronous above 95 deg east longitude (Statsionar 15).

MOLNIYA-1 (66), 1985-103A, 16220

Launched: 1725, 28 Oct 1985 from Plesetsk by A-2-e.
Spacecraft data: similar to Molniya-3 (26)
Mission: Communications satellite providing telephone, telegraph and television links through the 'Orbita' system.
Orbit: Initially 465 x 39129 km, 702.41 min, 62.80 deg; then raised to 465 x 39920 km, 717.80 min, 62.80 deg to ensure daily ground track repeats.

STS-61A, 1985-104A, 16230

Launched: 1700*, 30 Oct 1985 from the Kennedy Space Centre.
Spacecraft data: Shuttle orbiter 'Challenger'.
Mission: Carried Federal Republic of Germany's dedicated Spacelab D-1. Scientific aspects of the mission, which included some ESA experiments were controlled from the FRG. Crew consisted of Hartsfield, Nagel, Bluford, Buchli, Dunbar, Furrer (FRG), Messerschmid (FRG), and Ockels (ESA – Netherlands). 'Challenger' landed at Edwards AFB at 1744 on 6 Nov.
Orbit: 322 x 333 km, 91.05 min, 56.99 deg.

GLOMR, 1985-104B, 16231

Launched: 0534*, 31 Oct 1985 from the payload bay of 'Challenger'.
Spacecraft data: Multi-facetted spheroid, 0.41 m diameter, mass 68 kg.
Mission: Global Low Orbiting Message Relay satellite designed to test the feasibility of interrogating and controlling from space, remotely sited military sensors.
Orbit: 318 x 333 km, 91.01 min, 56.99 deg.

COSMOS 1701, 1985-105A, 16235

Launched: 0820, 9 Nov 1985 from Plesetsk by A-2-e
Spacecraft data: Possibly similar to Molniya-3 (26).
Mission: Missile early warning satellite.
Orbit: Initially 615 x 39300 km, 708.87 min, 63.05 deg; then raised to 619 x 39719 km, 717.45 min, 63.04 deg to ensure daily ground track repeats.

UPDATES:

1985-26A, **COSMOS 1643** re-entered or was recovered on 18 Oct after 207 days – the longest USSR photo-reconnaissance flight to date.

1985-28C, **SYNCOM IV-3** is now in geo-synchronous orbit above 175 deg west longitude after its boost motor was fired on 27 Oct. It had been repaired at the end of August by the crew of STS-51I (1985-76A).

1985-64A **COSMOS 1670** – the nuclear reactor powering the radar was separated and boosted to a 950 km circular orbit on 23 Oct.

1985-72A, **COSMOS 1677** the nuclear reactor powering the radar was separated and boosted to a 950 km circular orbit on 23 Oct.

SHUTTLE LAUNCH SCHEDULE 1986

Launch date	*Orbiter/Mission*	*Main Payload*
January 22	Challenger 51L	Spartan-Halley, TDRS-B1.
March 6	Columbia 61E	Astro-1.
March 20	Discovery 62A	DoD.
May 15	Challenger 61F	Ulysses.
May 20	Atlantis 61G	Galileo.
June 24	Columbia 61H	Westar VI, Palapa B3, Skynet4A.
July 22	Challenger 61M	EOS-1, TDRS-D.
August 18	Atlantis 61J	Hubble Space Telescope.
September 4	Columbia 61N	DoD.
September 27	Challenger 61I	Insat 1C, LDEF-1 (retrieval).
September 29	Discovery 62B	DoD.
October 27	Atlantic 61K	EOM 1/2.
November 6	Columbia 61L	MSL-3, GSTAR-3, SYNCOM-5.
December 6	Challenger 71B	DoD.

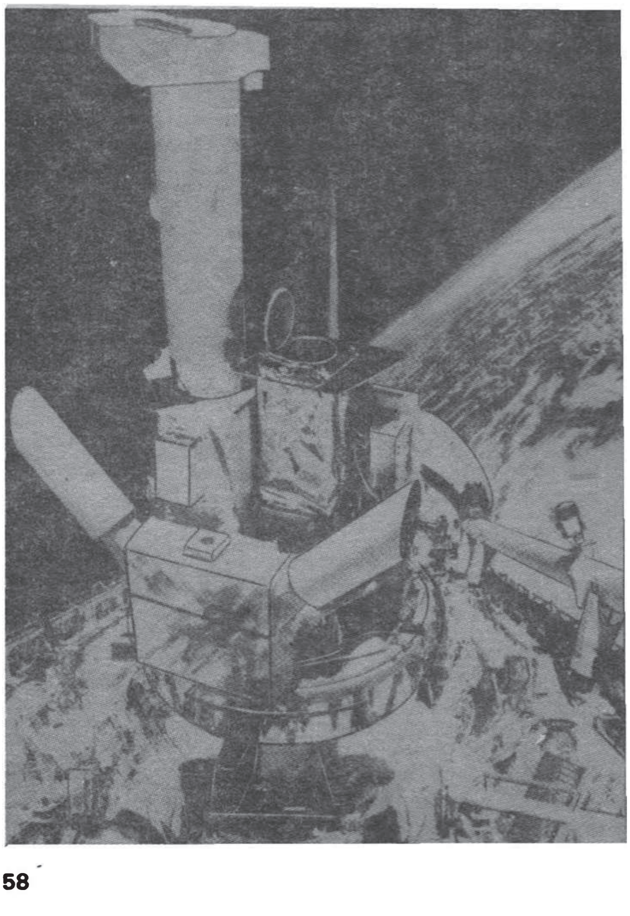
TOP REPUTATION FOR SPACELAB

It is interesting how quickly the public takes for granted what it had thought miraculous only a short time before. This is certainly true in the space business: it was not long ago that Spacelab proved to the world that Europe had "come of age" in manned-flight terms, but its continuing success has not received all the attention it has merited.

Its flexibility is the key not readily seen in the early stages of development by many potential users. Spacelab 1 opened the era of shirt-sleeve laboratory conditions with the accent on the use of payload and mission specialists as the "arm" of the experimenter sitting back on Earth.

Less spectacularly, but of very great importance, Spacelab 2 has shown the versatility of the pallet-only mode. It carried 11 USA experiments and two from the UK, in such diverse disciplines as life sciences, plasma physics, IR astronomy, high energy and solar physics as well as technological payloads. The main objective of the flight was to verify the Igloo and the Instrument Pointing System (IPS).

The Instrument Pointing System in orbit during the Spacelab 2 mission.



The Igloo contains all the necessary subsystems to service the experiments. When the module is flown they are housed in the core segment, but in the pallet-only mode they must be housed in a pressurised environment. The Igloo provides a dry air environment at normal Earth atmospheric pressure and is attached vertically to the forward end frame of the first pallet in the pallet-only mode. It worked perfectly, to the extent of hardly being mentioned or seen – rather like Father Brown's postman, although thankfully with positive rather than hostile results to those it served.

The IPS was paid a left-handed compliment by some observers. It had never been tried out in a space environment, and ESA and NASA had stressed that this first flight was intended to verify and calibrate the system. But space scientists can be impatient when faced with limited flight time, and some begrudged the hours it took to adjust the Sun acquisition and other techniques. In the end the accuracy, within the one arc second specified, was an apt tribute to those who had stood by this very real innovative equipment. Those experimenters who require such fine pointing precision can have confidence in IPS.

It is reported that data from the IPS-mounted Solar Optical Universal Polarimeter (SOUP) is the best run of solar granulation data ever collected. For instance:

- The birth of a spicule, one of the irregular distribution of jets shooting out from the Sun's chromosphere, was witnessed and photographed by the High Resolution Telescope with a new degree of detail.
- The Plasma Depletion Experiment (PDE) using the Plasma Depletion Package (PDP) monitored plasma turbulence caused by the Shuttle's motion. It showed that the Orbiter Manoeuvring System (OMS) when fired does create "holes" in the ionosphere which persist for longer than an hour. The crew and ground observers noticed airglow after OMS had been in use at night.

The list of success stories from other experimenters continues as post flight analyses are carried out: from ESA's viewpoint the message is clear – the pallet-only mode of Spacelab is a confirmed, space-qualified addition to the Space Transportation System.

Spacelab 3, in orbit before Spacelab 2, had a very mixed live contingent on board. In addition to the human crew of seven, there were two monkeys and 24 rats. Readers will have seen amusing pictures of astronauts chasing food "bubbles" in microgravity, but a rather more serious aspect of the problem was highlighted when crumbs and waste matter from the animal holding facilities were blown around the cabin.

The versatility of the Spacelab module was again demonstrated, for in addition to the life sciences there were material processing, fluid mechanics, astronomy and atmospheric science experiments on board.

The D-1 mission has received much acclaim, and deservedly so. The German national authorities are delighted, and so is ESA. Once again the Spacelab module lived up to its reputation, and so did the ESA-provided facilities – Sled, Biorack, and the Fluid Physics Module.

EUROPEAN RENDEZVOUS

For people in the space business, Spacelab is now an "everyday event".

ESA REORGANISATION

When the Ministers made their decision to give ESA a series of long-term programmes, it was axiomatic that Professor Reimar Lüst, the ESA Director-General, would want to take a careful look at the ESA organisation and re-align the structure to meet the new commitments. This has now been done, and from the programme point of view the most significant new developments are:

- the advent of a Directorate of Space Station and Platforms, which will concentrate on Columbus, Eureca, and other aspects of Space Station and associated platform development.
- the concentration of the Directorate of Space Transportation Systems on future Ariane development and Hermes questions.
- the bringing together of Earth Observation and Microgravity research.
- Telecommunication thereby becomes a separate directorate.

In addition several of the directorates have seen the need to allocate specific responsibility for the development of payloads for Eureca, Space Station, and associated platforms. This is most encouraging and suggests an awareness of the many disciplines which could benefit from the new dimensions that Columbus will offer.

Norman Longdon
European Space Agency

TV RELAY SATELLITE FOR UK

Plans to provide the UK with a telecommunications satellite for the relay of TV programmes to ground cable distribution systems could be finalised soon.

Eutelsat, Europe's telecommunications organisation, is currently negotiating for the aquisition of an additional satellite in the second generation Eutelsat 2 series.

Final approval for the purchase, prompted by British Telecom's request for provision of spacecraft capacity, is expected at the end of February.

Eutelsat originally planned to buy three Eutelsat 2 spacecraft so the dedicated satellite for British Telecom would bring the order to four.

BRITISH SPACE FUNDING

A British Union has called for the Government to increase the country's space budget by up to five times.

Chris Drake, Aerospace Organiser for the Engineering Union TASS, welcomed the news of the setting up of Britain's National Space Centre. (see Spaceflight, January 1986).

"Britain needs a Space Centre with strong Government backing. We also need Mr. Roy Gibson, the Director-General, and his colleagues to be accountable for what they do," he said.

The Union believes the new centre should urge immediately that adequate finance be given to British Aerospace's HOTOL space plane project and that Britain's space budget of £100 million should be increased to at least that of France, which currently spends five times as much on space.

News of the appointment of Roy Gibson as head of the Space Centre was welcomed by the council of the Science and Engineering Research Council (SERC).

SERC is currently discussing its future plans and is due to take a formal decision on participation at any time, although it has already indicated the desire to play a full part in British space efforts.

ARIANE TO HAVE LASER GYRO

Laser gyros will be used on the latest version in the Ariane family of launchers to help make more accurate guidance and trajectory corrections.

The gyros, to be fitted for the first time on the Ariane 4 series, will send angular and velocity information to the on-board computer.

They offer several advantages over traditional mechanical gyros, including increased reliability and a reduction in the number of parts.

The technique replaces the rotating mass of a mechanical gyro with laser light beams that follow fixed paths inside an optical block.

During launch of an Ariane 4, the first of which is scheduled for August this year, two laser gyro inertial reference systems (IRS), manufactured by French electronics firm Sfena, will be used simultaneously.

SUN OBSERVER

The European Space Agency's Ulysses Sun observation spacecraft has been recertified for launch after being taken out of storage. It is due for launch by the Space Shuttle and a Centaur Upper Stage in May.

Ulysses was put in store over two years ago due to changes in the programme which included a switch to the new Centaur Upper Stage for insertion into an orbit that will take it out of the plane of the ecliptic and over the Sun's poles.

HIPPARCOS LAUNCH BOOKED

The science satellite Hipparcos will be launched during the summer of 1988 by an Ariane 4 following the signing of a contract between ESA and Arianespace.

A contract for the launch of ECS 4, built by British Aerospace, has also been agreed between Arianespace and ESA for the second quarter of this year.

Completion of ECS 4, originally scheduled for launch in early 1987, was accelerated by BAe following the loss of ECS 3 due to the launch failure of Ariane V15 on September 12, 1985.

Arianespace is providing the earliest available launch slot for the new satellite in accordance with the re-launch conditions contained in the ECS 3 contract.

The Earth by Giotto

This is the Earth (top right) as seen by Giotto from a distance of more than 21,000 kilometres and in comparison by a weather satellite (lower picture) in geostationary orbit.

The images were taken by the Halley Multicolour Camera (HMC) and the GMS-3 weather satellite both looking at the Earth from 140 degrees east longitude.

Giotto's picture was taken 42 minutes before the weather satellite image and from a southerly declination of minus eight degrees, rather than from the equator.

The Sun-Earth observing platform phase angle was therefore 10 degrees smaller for the HMC image and the Earth was as a result slightly "fuller."

At a distance of 21 million kilometres when the picture was taken, Giotto was some 600 times further away from the Earth than the geostationary weather satellite.

Comparison of the pictures reveals a good correlation of the cloud formations, although in black and white only ten grey-scale levels are reproduced.

The HMC, part of Giotto's scientific payload, is a high resolution imaging system specially designed to operate from the rotating, spin-stabilised (15 rpm) space probe.

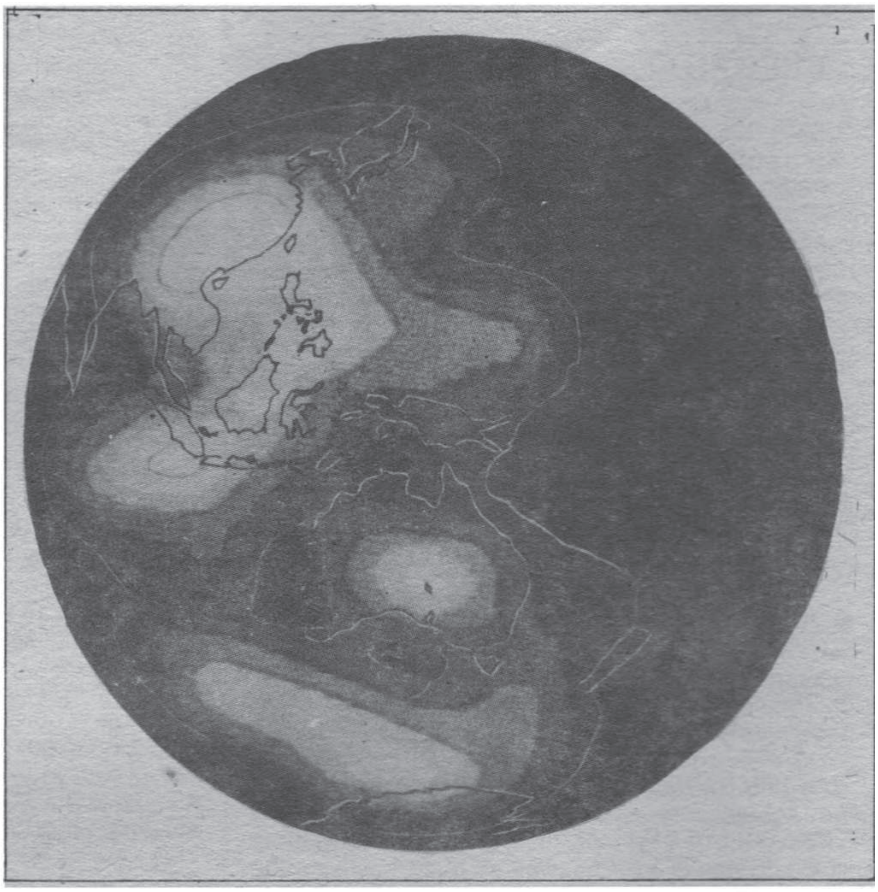
It will function in a completely self-contained, automatic mode during the fast flyby of the Comet Halley nucleus and can acquire and track the comet automatically.

The scientific objectives of the HMC are to detect the cometary nucleus and to investigate its size, shape and morphology, as well as the interaction of gas and dust during the evaporation process, by providing images in various filter bands.

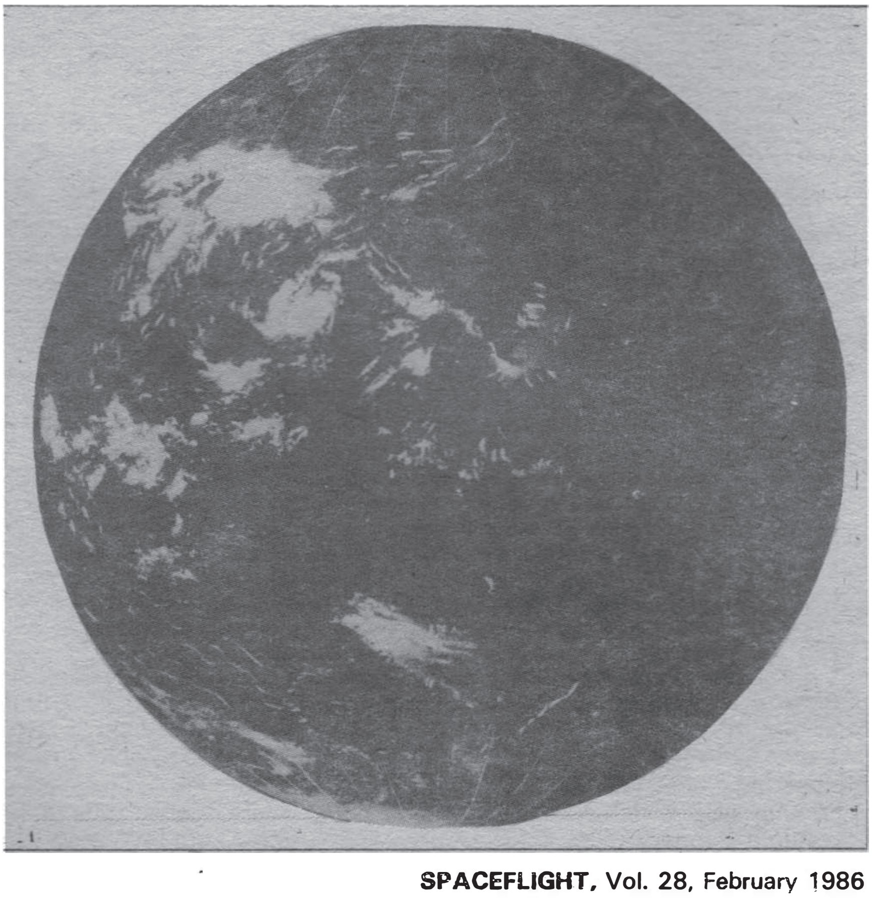
The complex operation of the HMC is controlled by three microprocessors using about 50 kilobytes of onboard software.

Following initial tests involving the observation of Jupiter and the star Vega, the camera was rotated by 135 degrees to look back at the Earth on October 18 and 23.

At that time the apparent diameter of our planet corresponded to only two arcminutes, or one fifteenth of that of the lunar disc as seen from Earth.



Pictures: ESA



SOVIET SCENE

VENUS UNVEILED BY VEGA PROBES

By Stephen Byford

Soviet scientists are now busily analysing the mass of information received from the Vega probes which landed successfully on the surface of Venus last summer. Some of the first results of their labours have now been made available.

On June 9, Vega 1, which was launched on December 15, 1984 drew close to the planet after travelling some 500 million kilometres. Explosive charges were then fired automatically, causing the Venus descent capsule to separate from the other part of the spacecraft, which will visit Halley's comet.

In the early morning of June 11, the descent module hurtled into the Venusian atmosphere at about 11 km per second. It was then about 125 km above the planet's surface.

This capsule then divided into a landing module and a balloon-carried sensor module, as planned. The former made a successful soft landing on Venus' surface, whilst the balloon section began to drift at an altitude averaging about 50 km.

The winds of Venus carried the balloon a total distance of about 10,000 km, from the night side to the day side. Its horizontal speed was 60 to 70 metres per second. Scientists were surprised to discover that the probe was being bounced 200-300 metres up and down by atmospheric currents reaching speeds of a metre per second. This gave a dramatic picture of the atmospheric turmoil on our sister planet.

The second Vega probe was close behind the first, entering the atmosphere of Venus and separating into lander and balloon on June 15.

The exact trajectories of the two balloons have been recreated almost completely by Soviet, American and French scientists. The results are based on the work of an international radio astronomy experiment involving radio-telescopes based in the Soviet Union, West Germany, France, Spain, Italy, Sweden, the United Kingdom, the Netherlands, Brazil and Australia. A study of these trajectories will help to determine large movements within the Venusian atmosphere, and should shed light on the dynamics of pressure and temperature within it.

Pravda, the official Soviet newspaper, reported that the second descent module landed in the northern part of Aphrodite Land, one of at least two Venusian continents. The lander from Vega 1 came to rest somewhat to the north of this, in Mermaid Valley.

The Vega landers were designed to continue the work of earlier Soviet probes in the Venera series. These had shown that whilst physical conditions on Venus differ greatly from those on our own world, nonetheless there are interesting similarities in topography and geological structure between the two planets.

Pictures of the Venusian surface from the earlier Venera probes had raised several interesting questions, the answers to which would be crucial to an understanding of the evolution and structure of the planet. What, for example, are the chemical composition and physical properties of the rocks on Venus

Venera 8 represented the first attempt to answer such questions. By analysis of gamma radiation spectra it measured the content of natural radioactive elements in the rock. It was found that the content of uranium, thorium and potassium in some Venusian rock was similar to that in the alkali eruptible rocks of the Earth's crust.

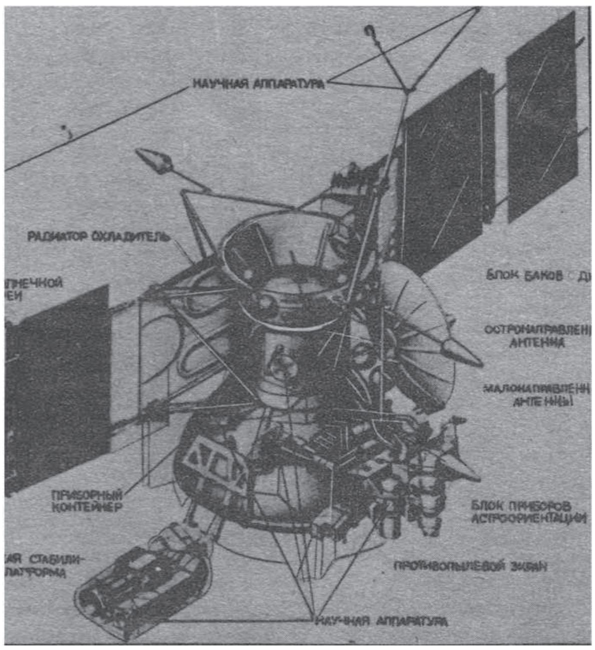
Such studies were continued by Veneras 9 and 10 in other regions of Venus, where the radio-element content of the rocks proved to be close to that of terrestrial tholeitic basalts.

In order to fully characterise the rock types and to understand the processes involved in their formation it is necessary to establish their chemical composition. This task was included in the programmes for Veneras 13 and 14 and the two Vegas.

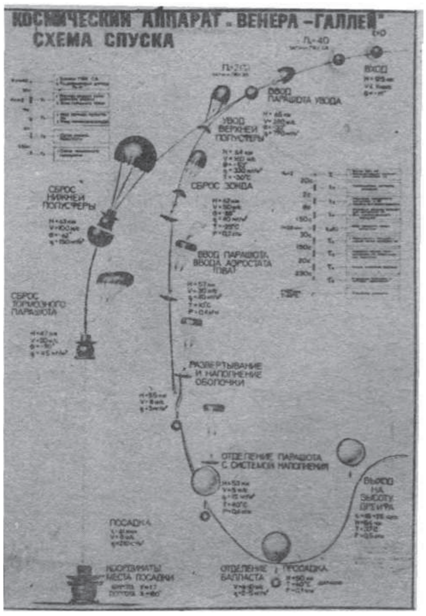
On these missions, a special soil sampler, capable of operating at temperatures up to 500 degrees celsius and pressures up to about 100 atmospheres, delivered soil into the lander. The analysis of the soil then took place inside the sealed lander, because there is no suitable equipment available at present that can operate in the harsh climatic conditions existing on the surface of Venus.

In Aphrodite Land, Vega found a type of rock, called anorthosite-troctolite, which is very rare on the Earth. It is nonetheless typical of the primary continental crust on both the Moon and Mars. There it represents some of the very oldest rock, with an age of some 3.8 to 4.6 billion years, whereas on the Earth it is much younger and in quite a different geological situation. This raises

Diagram showing the main sections of Vega.



SOVIET SCENE



Descent profiles for the Vega landers and balloon probes.

a question which has provoked much discussion: was there once a crust of this type on Earth and Venus, or did such crusts only appear at the final stages of the evolution of the relatively small planetary bodies like the Moon and Mars?

In terms of its mass, its size and the amount of energy it receives from the Sun, Venus is the most Earth-like planet known. Some of the latest information released by the Soviets, however, concerns the atmosphere and climate of Venus. In these respects the differences between the two worlds could scarcely be greater. For example, the two Vega spacecraft landed in an environment with a temperature of 452 degrees celsius, at a pressure of 86 atmospheres.

The composition of the Venusian atmosphere contrasts sharply with our own. There the most abundant gas is carbon dioxide, which accounts for only a thirtieth of one percent of the air here. But perhaps the most striking feature of Venus is its dense layer of cloud. This completely surrounds the planet, forming an unbroken shell.

The Vega descent modules carried several instruments designed to analyse the chemical composition of the clouds, and to measure the size and altitude distribution of the constituent particles. Details such as these are necessary if the precise role of the clouds in the absorption and diffusion of solar radiation is to be established.

Investigations carried out more than a decade ago using Earth-based telescopes suggested that the upper layers of the cloud blanket were composed of water-diluted sulphuric acid. Later, the infrared spectrum detected by Soviet probe Venera 15 contained lines which clearly confirmed the presence of the acid. These long-range observations, however, were unable to penetrate to the lower cloud layers.

The Vega descent modules each contained two experiments to measure the sulphuric acid content of the cloud particles. Firstly, there was Sigma 3, which contained a miniature chemical reactor and a gas chromatograph. This device gave consistent results on both probes, showing that, between the altitudes of 48 and 63 km, each cubic metre of Venusian atmosphere contains one milligram of sulphuric acid. This was corroborated by the second experiment, a joint Soviet-French package consisting of a mass spectrometer and an aerosol collector.

Another experiment carried by the Vegas has shown that sulphuric acid is one of many chemical components of the clouds. X-ray excitation of small samples of cloud material detected the presence, in comparable quantities, of the elements sulphur, chlorine and probably phosphorus. It is possible that some of the sulphur exists in a free state, giving the clouds a yellow tinge. This would be consistent with the findings of another instrument, the joint Soviet-French ultraviolet spectrometer.

The Vega modules also carried devices to measure some of the physical properties of the clouds. One of these measured the light diffusing properties of the cloud medium, another counted the number of particles passing through its field of view. Analysis of the results of these suggests that most of the particles in the Venusian clouds are several tenths of a micron across. (A micron is a thousandth of a millimetre.) This is comparable to a thin fog on the Earth. The probes found two layers of maximum cloud density, at 50 and 58 km altitude. They were each some three to five km thick.

The results of the particle counting experiments appear to be mutually consistent, but conflict with that carried by the American Pioneer-Venus probe in 1978. This, the only similar experiment ever performed, found a much greater abundance of larger particles with diameters of several microns.

There is also an interesting difference in the latest results from those of earlier Soviet probes, starting with Veneras 9 and 10 in 1975. Measurements of the light diffusing properties of the clouds compared with the particle count have previously shown an abrupt drop in the optical density when the probe descends past an altitude of 48-49 km. Neither of the Vega probes found such a discontinuity. Instead they found a fairly high optical density down to about 35 km, which gives a surprising new picture of major changes in the cloud structure extending over huge areas of the planet, since the two Vega probes landed about 1500 km apart and yet gave quite similar readings.

This therefore raises a new question: are these changes indirectly related to violent events within the planet, such as volcanic eruptions, or are they the result of climatic changes analogous to changes in the weather on Earth? If the latter is the case, as seems more likely, then the accepted models of the Venusian atmosphere will need to be revised.

Soviet scientists say that they are well pleased with the performance of the two probes. They believe that this project, which has involved considerable international co-operation, will contribute substantially to an understanding of our neighbouring planet. Meanwhile preparations gather pace for the next stage in the Vega project: the enounter with Halley's comet in March.

TIMETABLE TO EVACUATION

The complete evacuation, rather than partial crew relief, of Salyut 7 in late November has fuelled speculation that there are plans for a new Space Station.

Soviet space observer, James Oberg, believes it is now likely the station will be replaced by a new generation Salyut during the coming year, possibly sooner than would have otherwise been the case.

Sources point to the new Salyut being an advanced version of the standard model flying since 1971, probably the long-awaited "third generation" station with lateral docking ports.

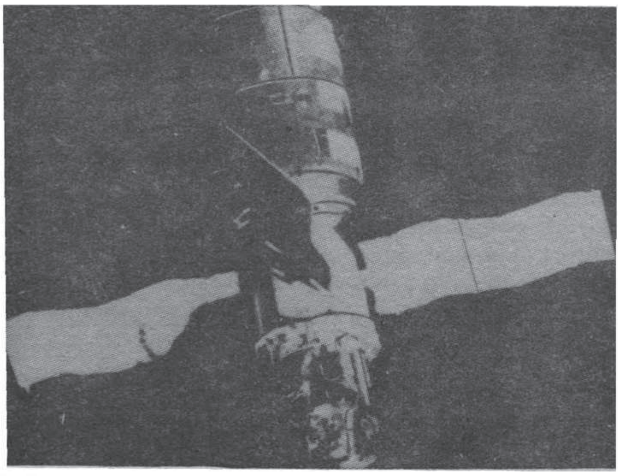
Meanwhile, it has now been possible to piece together a brief record of some of the events which led to the unscheduled return to Earth of the three cosmonauts aboard Salyut 7 on November 21.

Oct 25: It was stated that the cosmonauts were in "good health and feeling well" but from then onwards there was, unusually, no further mention of "health".

Nov 13: Communications between ground controllers and the cosmonauts were scrambled to prevent US interception.

Nov 13: No further reports of crew activity were given after this date.

Nov 21: Crew lands with no advance announcement one hour before sunset and mission commander Vladimir Vasyutin is taken to hospital. No further reports of his condition are issued.



The Salyut 7 Space Station.

It is worth noting that earlier landing windows on November 17 through to 20 had poor lighting conditions so the November 21 date was the first good opportunity with reasonable daylight for recovery operations.

However, in a life-threatening emergency the cosmonauts could have returned at any time, suggesting that the circumstances in this case were not too urgent.

Despite the problems during the reactivation of Salyut 7 for its recent occupancy and the cosmonaut illness leading to an early termination of the mission, much valuable scientific work was accomplished. Below Neville Kidger reports on these activities.

SALYUT MISSION REPORT

By Neville Kidger

The last two weeks of August were busy ones for the Pamirs — cosmonauts Dzhanibekov and Savinykh — as they continued their flight on the Salyut 7, Soyuz T-13, Cosmos 1669 complex. The emphasis of work was on Earth and atmospheric observations with continuing interest in the technical performance of the revitalised Salyut station. The cosmonauts conducted a test of Salyut's solar panels to assess their performance at varying angles of solar illumination and also to test the small solar panels which they had erected alongside one of the main solar panels during an EVA on August 2, 1985.

Photography, spectrometry and radiometric observations of the Earth's atmosphere over the area of Zaporozhye were conducted on August 16 in order to evaluate atmospheric pollution over industrial centres.

The cosmonauts continued to take photographs and collect other data over the Kursk and Azerbaijan test areas as part of the Kursk-85 and Gyunesh-85 remote sensing experiments. Simultaneous observations of the areas were conducted by aircraft and ground crews to provide a complete picture of the conditions. The Soviets say that similar experiments in 1984, conducted during the 237 day space marathon, provided valuable data which enabled specialists to map out the most economical grazing pastures for livestock, map forest regions to ascertain the existance of pests and find underground water reservoirs.

The Soviets stress the work done by the cosmonauts on Salyut in the areas of remote sensing and say that some 700 institutions and industrial plants use space-derived data. It is claimed that space photography of the route of the now-opened Baikal to Amur railway has helped to save an estimated R7 million.

As the days of September passed, the cosmonauts conducted further science experiments. They spent time on further tests of the Elektrotopograph device which analyses minute variations in the surfaces of materials exposed to raw space via the Salyut airlock. On September 3 TASS reported that the docking module of Salyut had been depressurised as part of this series of experiments to expose samples to space.

On the same day TASS also said that the men were conducting experiments with the Biryuza and Analiz

equipment with the aim of investigating "the processes of growing crystals from solutions and molten baths in microgravity conditions".

For a week, from September 6 to 13, TASS made no mention of the flight and said that the men had been conducting astrophysical, technological, medical and biological experiments as well as photography and visual observations of the surface of the Earth.

The week also saw further observations with the Mariya unit and another cycle of Elektrotopograph tests. TASS noted that the cosmonauts were testing their cardiovascular system with the Chibis hydrostatic suit which used negative pressure to simulate the pull of Earth.

The cosmonauts had succeeded in growing Central Asian cotton in their Oasis "green-house".

Soyuz T-14 in Flight

At 1239 GMT on September 17, 1985, the Soyuz T-14 spacecraft was launched into azure skies at the Baikonur Cosmodrome. The spacecraft had three crew led by cosmonaut Lt-Col Vladimir Vasyutin, call sign Cheget. The flight engineer was Georgi Grechko, a veteran of two long space-flights, and the researcher-cosmonaut was another Lt-Col, Aleksandr Volkov.

Soyuz T-14 Mission

Following the fourth orbit correction of its trajectory Soyuz T-14 was in a 274 x 325 km orbit. Docking was accomplished at 1415 GMT on September 18 after a normal rendezvous profile. After checks of the hermeticity of the docking seal the hatch was opened at 1724 GMT and the Chegets crew of three were warmly welcomed by Dzhanibekov and Savinykh.

In its announcement of the docking, TASS said that the joint flight would last for eight days and that the men would conduct a varied programme of research. The news agency also stated: "in accordance with the planned programme work at the station will be continued by Vladimir Vasyutin, Viktor Savinykh and Aleksandr Volkov, whilst Vladimir Dzhanibekov and George Grechko will return to Earth in the Soyuz T-13 spaceship."

"Partial" relief of the Salyut crew was an interesting addition to the Salyut saga. In July 1984 Prof. Roald Sagdeev had been quoted in an American magazine as saying the Soviets had no plans to premanently man the Salyut 7 station. In retrospect, as pointed out by analyst R. Hall, it would seem that the original crew for a March 1985 mission to Salyut consisted of Vasyutin, Savinykh and Volkov. When Salyut malfunctioned Dzhanibekov and Savinykh were paired to fly the repair mission and when the two men had completed the task the original crew would be formed on the station. Because Dzhanibekov needed a flight engineer for the return to Earth in Soyuz T-13 Grechko was included in the Soyuz T-14 crew.

During the short flight of the five men in Salyut some interesting new experiments were begun. At one point 10 instruments, including SKIF, were simultanously engaged in atmospheric studies. These included the Czechoslovakian EFO-1, to study the passage of starlight through the horizon and cine filming of sunrise and sunset.

Photography of the surface of Earth was conducted and included areas of the Black Sea, in coniunction with Soviet and Bulgarian scientists on aircraft and ships. The "Black Sea-85" experiment had as its aim remote sensing of the "hydrophysical and biological characteristics of the water surface."

Soyuz T-14 delivered a "pilot-scale" electrophoresis processing unit, called EFU-Robot, which was described as being fully automated and able to produce pure preparations needed by the Soviet Health Service, food industry and agriculture.

In biological investigations the Chegets sowed cotton seeds from Uzbekistan in one of the station's greenhouses and conducted an experiment in the Svetobloc-T installation "to produce a synthetic gel which can be used for the electrophoretic purification of substances on Earth".

Return of Soyuz T-13

At 0358 GMT on September 25 Soyuz T-13 undocked from Salyut but the cosmonauts did not return home that day, as would have been normal. Instead they spent the day station keeping with Salyut and practicing approaches to the station (although there were no reports of actual redocking).

Soyuz T-13 landed the next day, September 26, at 0952 GMT. The Soviets said that the landing, some 220 km northeast of Dzhezkazgan in Kazakhstan, was accomplished in "unusually clear and warm" weather conditions.

Cosmos 1686 Takes Flight

The day after the landing, TASS announced that Cosmos 1686 had been launched. The satellite, "similar in design" to Cosmos 1267 and Cosmos 1443 went into an orbit of 178 x 320 km with an orbital period of 89.2 minutes and an inclination of 51.6 degrees. The satellite was one of the "heavy" Cosmos satellites launched by the Proton booster and weighing about 20 tonnes.

Cosmos 1686 docked with Salyut's front docking unit at 1016 GMT on October 2. The Soviets said that Cosmos would be used for tests of its equipment and units and "further optimisation of control methods" as well as the conducting of scientific research. Cosmos had also delivered supplies of equipment, apparatus and "miscellaneous freights" to keep the complex functioning.

MARS MISSION EXPERIMENT

A particle experiment for the Soviet Union's 1988 interplanetary mission to Mars and Phobos is in the final stages of development at Sweden's Kiruna Geophysical Institute.

Called Aspera, it will measure electrons and positive ion distribution/composition, using a rotating system to scan from the three-axis stabilised spacecraft.

The Soviets plan to launch two spacecraft on the Mars/Phobos mission in 1988 to gather data on the planet and its atmosphere, as well as detailed information on Phobos.

During the 200 day journey to Mars the spacecraft will also study the solar wind and cosmic rays.

VIKINGS ON SPACE PATH

By L. J. Carter

The Stockholm Congress was an excellent opportunity to obtain information at first hand about the Swedish space programme which, although small, is surprisingly diversified and ambitious in scope.

Swedish Board for Space Activities

The Swedish Board for Space Activities (SBSA) was created in 1972 under the Ministry of Industry. It is a government agency responsible for the Swedish national and international space and remote sensing programmes, particularly in regard to research and development.

Its most important task is to promote the development and allocation of space technology within Swedish industry and to support scientific programmes which need new space technology for its experiments. SBSA is also the contact point with the European Space Agency (ESA).

In 1979 the Swedish Parliament decided to increase the funding of space activities by a factor of three. The aims were to create technical know-how with a view to establishing a profitable space sector, at system and subsystem level, both at home and abroad: build up industrial competence in a field of vital national interest, using advanced technology, and to improve the competitive position of Swedish industry and trade in general.

The 1979 decision is now being implemented with the first Swedish satellite – the scientific satellite Viking launched in 1985 – followed in 1987 by the telecommunications satellite Tele-X, both using Ariane.

In 1984 the SBSA submitted a long-term plan for Swedish space activities for the period up to 1991. Among the suggested projects is continued development based on experience with Viking but seeking different applications, especially telecommunications, with the possibility of launching low-cost satellites from Esrange also suggested.

The Swedish space budget for the fiscal year 1985/86 amounts to 443 million Swedish crowns (SEK). Of this amount 150 million SEK constitute the Swedish contributions to the European Space Agency (ESA) and to projects undertaken in cooperation with other countries: the rest is allocated to the national programme.

By object, 66 million SEK is devoted to science, 43 to remote sensing, 66 to industrial development, 218 to the Tele-X project, 15 to the ground station Esrange, 30 to ESA Basic Activities and five to administration.

Industrial Involvement

Development of an industrial base is borne out by the fact that, over the last decade Volvo Flygmotor has provided 300 combustion chambers for Ariane Viking engines and now participates in pre-development technology studies of the next generation Ariane engine HM60 as well as conceptual studies for a Post-HM60 engine. Current production and recently obtained contracts for future production will satisfy the need of chambers for both Ariane 3 and Ariane 4, scheduled for launch in mid 1986. Production is based on an annual rate of seven launchers and will continue into the nineties.

The company is also involved in studies of Electric Propellant Pump Systems for Orbit Transfer Propulsion Systems and Energy Storage Wheels for space platforms.

In recent years Volvo Flygmotor has enlarged its activities to participate in the pre-development studies of the cryogenic HM60/Vulcain engine for Ariane 5, to carry the heavier payloads foreseen over the next decade.

Viking – Sweden's First Satellite

This is really an advanced mission at low cost built by Saab Space. Launch is in a piggy-back arrangement with the SPOT satellite. It has two main purposes:

(a) scientific – to perform advanced magnetospheric and auroral research

(b) policy – to increase Swedish industry's capabilities in satellite development work

Saab Space AB is prime contractor for the development of the Viking satellite on a contract from the Swedish Space Corporation. This includes:

(a) project management and product assurance

(b) systems engineering, mission analysis

(c) interface control and coordination (Viking-Spot, Viking-Ariane, Viking-Ground Station, Payload-Platform)

(d) payload development including radial booms and mechanisms

(e) TTC subsystem development

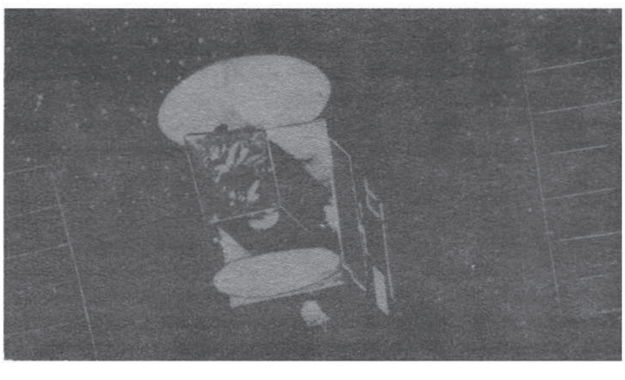
(f) procurement of the platform from the Boeing Aerospace Company

(g) payload and satellite integration and test

The programme is unique in its low cost approach, involving both the launch and satellite. Launch cost is kept to a minimum through the use of a load-carrying main structure which allows the efficient use of the extra payload volume. The satellite cost is kept low by making the maximum use of existing, previously qualified units, clearly defined and controlled interfaces, cost-effective working methods and routines and trade-offs between the requirements and cost.

The same low cost features are readily adaptable to a wide variety of small satellites for the same concept can

The Tele-X communications satellite.



be used with slight modifications for different payload types, larger payloads, different orbits (low circular, elliptical, geostationary), different attitude control (spinner or three axis stabilised), higher data rates etc.

Viking's Scientific Programme

Viking's main programme will be magnetospheric and auroral research by performing measurements with high data rates and high resolution in those regions of Earth's magnetosphere where charged particles are accelerated to high velocities along the magnetic field lines, causing auroral phenomenae at lower altitudes. The main region of interest is altitudes between 4,000 and 15,000 km at high latitudes, with emphasis on winter season measurements. The orbit chosen is elliptical with an apogee 15,000 km at northern latitudes, a perigee of 820 km and an orbital period of 4½ hours.

The scientific experiments involve electrical fields, (using tip sensors on four wire booms and two axial booms); magnetic fields, (using a magnetometer on a radial boom); energy and angular distribution of charged particles, (using several particle detectors); electromagnetic/particle wave phenomenae (using a boom mounted loop antenna and signals from the other boom sensors); ultra violet imaging of the aurora, (using two cameras with CCD array detectors, operating at two UV wavelengths).

Viking Configuration

The main data regarding the satellite are

height: ~ 0.5 m (~ 0.9 m inc. PBM nozzle)

diameter: ~ 2 m (stowed booms)

Mass: ~ 530 kg at launch (incl. ~ 263 kg for the PBM)

Structure
Cylindrical aluminium tube, 1.2 m dia. height 0.5 m, thickness 6 mm, giving adequate stiffness and strength to carry SPOT.

Communication
S-band link with Esrange ground station.

Power
Eight bodyfixed solar arrays with battery to provide backup during eclipses and peak consumption.

Attitude Control
Magnetic control *via* ground station to maintain spin rate 3 rpm and spin axis pointing perpendicular to orbit plane (cartwheel mode). Attitude data from Earth sensor and Sun sensor.

Propulsion
STAR 26C solid propellant Perigee Boost Motor (PBM).

Thermal Control
Three louvres (self adjustable, temperature dependent radiated power); thermal blankets (multi-layer insulation); different paints and other surface treatments.

Booms
4 wire booms, 40 m each; 2 axial booms, 4 m each; and 2 radial stiff booms.

Operation of the satellite and data acquisition will take place at Esrange, Kiruna.

Tele-X

Tele-X is a Swedish-Norwegian-Finnish telecommunications satellite, currently the main project in the national telecommunications programme. It has two TV channels and four stereo radio channels.

The satellite has several missions *viz:*

(a) direct broadcasting of TV and sound (DBS)

(b) data and video services for business communications

(c) permanent and temporary link services for TV and sound programme production

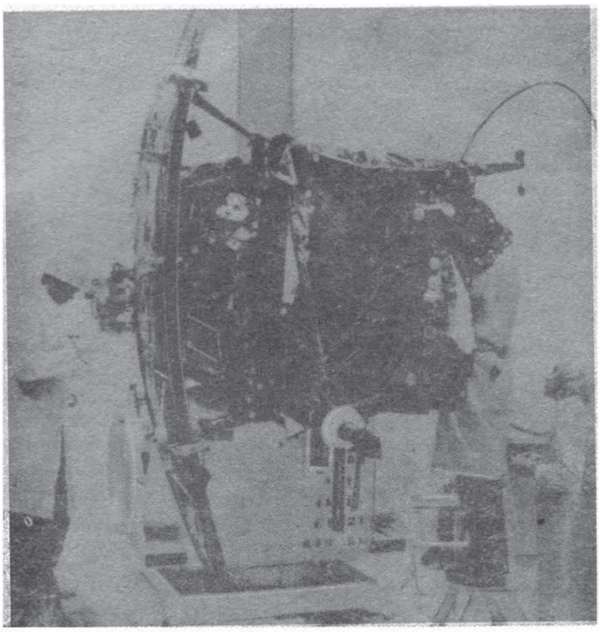
(d) closed-circuit TV, tele-education etc.

Launch into a geostationary orbit by Ariane is expected by the middle of 1987. It has an expected lifetime of seven years. It is seen as a first step on the way to realise a Nordic operational telecomunications satellite system. Agreements between the governments of Sweden, Norway and Finland regulate cooperation and financial commitments. Sweden is defraying 82%, Norway 15% and Finland 3% of the investment costs. The initial investment covers a satellite in orbit, facilities for satellite control and a limited number of Earth stations., The Swedish and Norwegian telecommunications administrations have together set up the Notelsat Company for the technical operation of the system.

The DBS part of the system is based on high transmitted power in the satellite (230 W) to allow direct TV reception in Sweden, Norway and Finland with antennae no more than 90 cm in diameter at the edge of the coverage area, and even smaller in the central part of the area. High power in the satellite is also the basis for business service and other data/video communications. This allows the use of small, inexpensive Earth stations.

The aim is to offer a completely new spectrum of communications possibilities. Business service is expected with a quickly growing market which will soon make it a profitable venture with, typically, the transmission of a printed page (300 words) in less than a second.

Assembly of the Tele-X antenna module at Saab Space in Sweden.



SWEDEN

Mailstar

Mailstar is a low-cost electronic mail relay satellite under study by Saab Space and Ericsson Radio Systems for the Swedish Space Corporation.

The satellite is to operate from a polar orbit and, *via* an on-board memory, carry telex- and telefax-type messages between ground stations all over the world. Delay time would be about 1-2 hours from transmission to reception of a message. A typical message could be 20-40 pages of text. The satellite passes all ground stations at least twice a day.

Space Science

Scientific activities of Swedish research cover the following:

- Magnetospheric and ionospheric physics, particularly measurements of charged particles and electrical and magnetic fields using satellite experiments, sounding rockets and balloons.
- Study of the upper atmosphere (80-150 km) particularly atmospheric processes and composition at high latitudes using sounding rockets.
- Astrophysics, particularly studies of stellar and extra-galactic UV radiation, IR studies, astrometry and meteor studies using satellites, sounding rockets and balloons.
- Material sciences, particularly solidification processes of metals and crystallisation in zero-g using sounding rockets.

Sounding rocket experiments and releasing of scientific balloons are carried out at Esrange, the Swedish space range close to Kiruna in northern Sweden.

Remote Sensing

The remote sensing programme involves a number of programme elements covering:

(a) basic research to operational applications

(b) ground based systems to satellite systems; (c) microwave-to UV-techniques

(d) all stages from satellite data reception to a variety of map and image products.

Swedish participation in the French SPOT project is an essential element of the remote sensing programme. Satellite Image Corporation, a company affiliated to the Swedish Space Corporation, has been established in Kiruna to generate, distribute and market SPOT products.

There has been a gradual build-up of resources for remote sensing activities. New advanced equipment has been made available through development or purchase and several major cooperative field experiments carried out. The aim of the Swedish remote sensing programme is to assess the potential of the technology and to acquaint potential users with this at an early stage. With users rapidly acquiring the resources and know-how necessary to carry out independent development work more effort has been spent on the development of methods and systems.

A facility for the reception, recording, filing, processing and dissemination of remote sensing satellite data was established at Esrange in 1978. The station was originally used for spacecraft in the Landsat series and operated within the framework of the European Space Agency's (ESA) Earthnet programme. The station is currently being extended to accommodate the new sensors carried by the Landsat-4 and SPOT satellites. Further extension to accommodate the European Remote Sensing Satellite ERS-1 and similar future satellites is also envisaged.

ESA-Cooperation

Sweden is a member of the European Space Agency (ESA) and participates in most of the optional application programmes of:

(a) the Ariane launcher project

(b) telecommunications, i.e. the European regional communication satellite programme (ECS), the advanced systems and technology programme (ASTP) and the preparatory programme for future telecommunications satellites.

(c) remote sensing, including ERS-1 and the programme for receiving, preprocessing, filing and distribution of images from remote sensing satellites, Earthnet. Esrange is part of this system and is collecting Landsat data on a routine basis.

(d) the microgravity programme.

Bilateral Cooperation

Cooperation between Sweden and France extends beyond ESA and includes bilateral agreements between CNES (Centre National D'Etudes Spatiales) and Swedish space authorities.

CNES is involved in major Swedish space programmes; Sweden has become (after ESA) the largest European customer for French space industry. In return, Swedish industry participates in CNES-run French national space programmes, besides partnership on certain foreign market projects.

A typical example of cooperation occurs with Tele-X which, although a Swedish programme for a multimission relay satellite specialising in direct TV and video data relay, is based on the platform developed jointly by France and Germany for the twin TDF-1 and TV-Sat programmes. SAAB-Scania, as prime contractor, joined with Aerospatiale for the operation, a contract being signed between SSC, Aerospatiale and Eurosatellite GmbH in August 1983, amounting to 650 MKS. The Tele-X payload has been contracted to LM Ericsson, with Thomson-CSF providing specialised equipment such as direct TV receivers and video data transmitters. CNES acts as a satellite and ground-based support design consultant.

Another example of Swedish-French cooperation is SPOT, with Sweden responsible for on-board computer development and manufacture for SPOT 1 and 2, as well as sharing a proportion of launch costs. A direct TV receiving station will be operational at the Kiruna range as well as a data pre-processing centre.

In reverse, CNES and SPOT Image participate in Satimage, a company operating the Kiruna SPOT station as well as the distributor of SPOT and Landsat data for Scandinavia.

Swedish industrial companies are also involved in the Franco-German TDF-1/TV Sat programme, their share being four per cent of total cost.

GALILEO FLIGHT ENGINEERING

In the December issue, science planning for the Galileo mission to Jupiter was discussed. This month the engineering side of the Galileo project will be examined.

Ralph Reichert is the manager of the Flight Engineering Office for Galileo. It was of particular interest to talk with him concerning his duties, because your correspondent occupies the same position on the Voyager project. Between the two projects we have many engineering problems and activities in common, but three factors introduce differences:

1. Voyager has been in flight since 1977. This is good because it means that spacecraft and ground support systems are in more of a settled, equilibrium posture than for Galileo, which does not launch until May 1986. It is not so good because the Voyager spacecraft, like all middle-aged organisms, is somewhat vulnerable to failure of parts.
2. Galileo will go into orbit about its planet – Jupiter. Voyager flies by its planets: Jupiter, Saturn, Uranus, and Neptune (1989). The differences induced by this factor are less than might be expected since the ten encounters with the four Galilean satellites resemble mini-planetary flybys.
3. Although the Voyager spacecraft is the most capable interplanetary vehicle flown to date, in most respects the newer Galileo spacecraft has even more capability.

The Galileo Orbiter is a dual-spin spacecraft; part of it spins, normally at three rpm, providing stabilisation and a favourable environment for fields and particles experiments. The de-spun (non-spinning) portion of the spacecraft furnishes a stable platform for remote sensing experiments like imaging. The Voyager spacecraft is three-axis stablised (ie: does not spin) while the Pioneer 10 and 11 spacecraft spin in their entirety.

There are four teams within the Flight Engineering Office: Orbiter Engineering, Probe Engineering, Navigation, and Sequence. The major functions of these teams will be reviewed. The reader who desires a generic view of mission operations systems should consult the October 1985 issue of JBIS, which is devoted to that topic.

The Orbiter Engineering Team contains about 45 people at launch (all of the teams will increase in size as Jupiter's orbit is approached in 1988 (staffing sizes quoted here will refer to configuration of the teams at launch). Three of the major functions of this team are: real-time operations, analysis, and generating engineering activity plans (eg: calibrations) together with review of on-board computer loads ("sequences") constructed by the Sequence Team.

Real-time operations are exemplified by the monitoring of Orbiter telemetry channels during flight to check that temperature, voltage and other parameters are properly behaved and to undertake corrective action in case of anomalies. The second function, analysis, usually proceeds at a slower pace but in more depth. Here, engineers adapt the Orbiter to the mission phase at hand and treat problems that may have arisen. Despite careful design and planning before launch, all spacecraft experience in-flight problems, in varying degrees of severity. Finally, the Orbiter Team generates engineering inputs and reviews all computer loads to be sent to the spacecraft to insure that they meet requirements and constraints.

The second team, Probe Engineering, is staffed by about 20 personnel from NASA's Ames Research Center (which manages the Probe) and from the Hughes Aircraft Company (which built the Probe.) The Probe is scheduled for release from the Orbiter 150 days prior to the entry of the former into the atmosphere of Jupiter. During entry it will relay data for about 75 minutes to the overflying Orbiter concerning the pressure, temperature, and composition of the Jovian atmosphere.

Unlike coverage for the Orbiter, (nearly) continuous telemetry data are not received on Earth from the Probe. These engineering measurements channels will not be turned on until August 1986, about three months after launch. At this time the state of the Probe, nestled snugly in the Orbiter, will be evaluated. The telemetry will be turned off after this evaluation and then monitored only at six-month intervals. A final check of the Probe will be done prior to release from the Orbiter. During the 150-day ballistic cruise to Jupiter, no telemetry or tracking data will be returned by the Probe. Its life terminates with a glorious burst of scientific data upon entry into the atmosphere.

The Navigation Team, with approximately 25 members, performs the classic functions of periodically estimating the trajectory of the Orbiter and designing manoeuvers to maintain the trajectory plan into the future. Precision navigation is required because the Orbiter's 22-month tour of the Galilean satellites (Io, Europa, Ganymede, and Callisto) features encounters as close as a few hundred kilometres above the surface of the satellites.

During each orbit, which typically lasts one or two months, three trim manoeuvers are planned. One takes place three days before encounter with the relevant satellite for that orbit, another trim occurs three days after encounter, and the third takes place at apoapsis (the most distant point on the orbit).

The trim before encounter is obviously designed to

"set things right" prior to the most crucial period of data gathering near the satellite. The trim after encounter restores the trajectory to its planned state after the relative violence that has been inflicted upon it by the close encounter with the satellite. A trim is done at apoapsis because the laws of celestial mechanics imply that this is a very fuel-efficient location at which to perform manoeuvers.

The Sequence Team also has 25 people and builds the on-board computer loads which control the activities of the Orbiter. Initial design work will have been done by the Science and Mission Design Office. "Sequence" refers to the sequence of computer commands which constitute each computer load.

During the cruise to Jupiter, each sequence will execute over a period of about four weeks (two-week periods are employed just after launch). Once in orbit the pace of activity will increase: three loads will be required in the ten-day period spanning closest approach to a satellite and two-week loads will fill the remainder of the orbit.

The data-system architecture within which the Galileo Sequence Team operates resembles its Voyager counterpart but differs from it in important ways. First, Galileo's computers are smarter; they can be instructed with higher-level code than Voyager's. Second, some of the computing system on Galileo is decentralised, being distributed to the spacecraft's instruments, and Galileo features two types of central computers compared to Voyager's three types. Third, Galileo's computers are larger than Voyager's, but ask any sequencer on any project and you will find that his computing resources are never large enough!

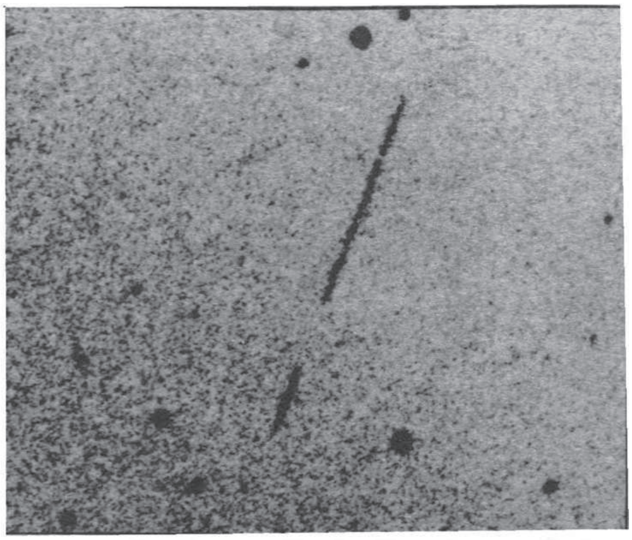
The Galileo engineering team is smart and experienced, many of its members have worked on interplanetary projects such as Viking and Voyager. They have an interesting set of challenges in front of them and will undoubtedly meet them with élan. We wish them success and the unique pleasures that an interplanetary mission brings. The Argonauts and Odysseus didn't exhaust adventure.

UNUSUAL ASTEROID DISCOVERY

On August 15, 1985, the JPL International Near-Earth Asteroid Search (INAS) discovered an asteroid of the Apollo type (crosses the Earth's orbit) with an orbit which has an unusually large inclination, 56 degrees, to the plane of the Earth's orbit.

The discovery was the culmination of an international effort. Eleanor Helin of JPL and ESA Fellow, M.A. Barucci, of Italy, observed the object at Caussols, France, with the 0.9 m CERGA Schmidt telescope, with support provided by CERGA Telescope Director J.L. Heudier.

Physical observations by D. Tholen and A. Tokunaga at Mauna Kea, Hawaii, were made just after the orbit became available. Their preliminary results indicate that the asteroid, designated 1985PA, is slightly reddish in colour which places it in the silicaceous surface composition category. The diameter of 1985PA is about one to two km and its rotational period is on the order of eight days. It orbits the Sun every 1.7 years in an orbit which is not only inclined but eccentric (e = 0.30). The large inclination of the orbit will make this object visible for an extended period of time, enabling a very good orbit to be computed for it.



The asteroid 1985 PA, appearing as a streak against the stellar background, is inclined at an unusually large angle to the ecliptic (plane of the Earth's orbit).

Eleanor Helin

Adding to the international aspect of the discovery was the set of supplementary observations of 1985PA provided by Helin's JPL asteroid team in California (S. Singer-Brewster, M. Rudnyk, and D. Schneeberger) using the 0.46m Schmidt at Palomar.

The discovery of asteroids is an important activity which is gradually filling in our picture of their population statistics and properties. Celestial objects with unusual dynamical properties, like highly inclined 1985PA, may contain more than the usual amount of information about Solar System processes and history: Uranus lying on its side, Triton orbiting Neptune in a retrograde orbit, and the braided F-ring of Saturn. The trick, of course, is to find the key to the puzzle which these situations pose. In the case of 1985PA, a collision with another asteroid is a possibility.

The discovery of 1985PA increases to 84 the number of known near Earth asteroids and is the 22nd discovery for the JPL search team since the beginning of their programme in 1973.

FUTURE MISSION TECHNOLOGIES

In order to conceive a mission and bring it to reality, one needs vision, technical skill, and funding support. What often lies in the background, unnoticed, is the technology that enables a particular mission to be accomplished.

Space flight as we know it would not be possible without certain technologies: computers, solid-state devices, television (for data collection and optical navigation). Other technologies, such as advanced propulsion techniques and sturdy heat shields, must be developed or greatly improved before interstellar flight or missions very close to the Sun can be undertaken. Still other technologies, solar-electric propulsion or optical-communication links, wait in the wings for the mission which needs them.

The Mission Design section at JPL is in the business of manufacturing and guiding missions and is now looking over its set of possible future missions to identify what new technologies may be required.

The topic of in situ propellant production on Mars

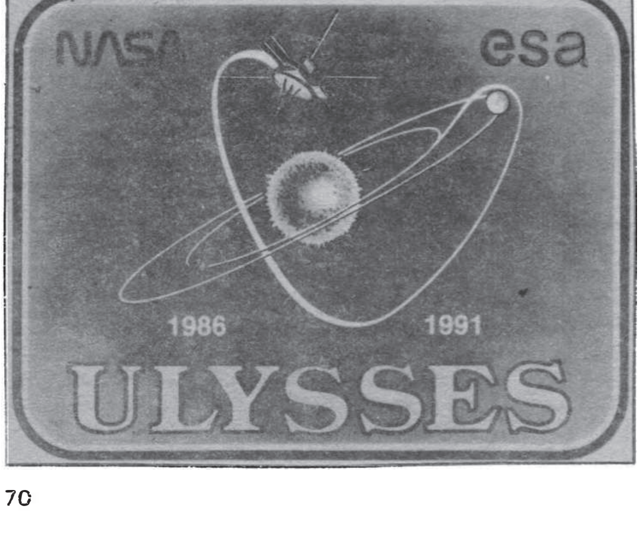
was discussed in the September/October 1983 edition of this column. In this scenario a Martian lander would produce oxygen for use as a propellant component to effect the lander's eventual lift off from the surface, after collecting samples of the Martian environment. This technology can also be used to produce oxygen to sustain a manned presence on Mars. In order to manufacture the oxygen, the system requires the intake of carbon dioxide from the Martian atmosphere, presumably via a mechanical pump. Two problems are presented by the pump: it would require a filtration system to clean the dusty Martian air, and devices with moving parts are vulnerable to break downs and consequent failure.

A proposed technological solution to this pair of problems is achievable by introducing an adsorptive material, in place of the mechanical pump. The material takes up the carbon dioxide as desired, filters out the dust, and is a reliable as the hills.

The Venus Orbiter Imaging Radar (VOIR) was the precursor to the present Venus Radar Mapper (VRM), scheduled for the 1988 launch. One conception that was entertained for VOIR, but is not part of the VRM plan, was the use of the atmosphere of Venus to effect aerocapture of the spacecraft from its incoming interplanetary trajectory. The technique holds promise for future missions and has been examined with regard to its navigational potential. A study has looked at the prospects of autonomous navigation during the aerocapture phase. The on-board computer programme would process data from a set of accelerometers and atmospheric-density measuring devices. The procedure would produce a quick and accurate emphemeris for the spacecraft during this critical mission phase, without suffering the delay introduced by ground processing. It would also prove valuable if ground tracking was not feasible for the aerocapture manoeuver.

Current comet missions are of the flyby type, future ones will rendezvous with a comet: JPL's proposed Comet Rendezvous/Asteroid Flyby mission. Still further down the celestial road we will see a sample return mission, wherein a spacecraft touches down on the nucleus, extracts a sample and returns to Earth. Studies done in conjunction with NASA's Johnson Space Center and Langley Research Center have examined some of the technological problems involved.

The Ulysses mission, a joint ESA/NASA project, will be launched in May of 1986 to study the fields and particles environment above the poles of the Sun.



One problem is to design a reliable drilling apparatus to sit on the surface of the nucleus. Clearly the design must reflect the topography of the nuclear surface. Simulations of this topography have been created by building a small iceball from a clay solution which is frozen by contact with liquid nitrogen (consistent with the nuclear model of Fraser-Fanale in Icarus 60, pp. 476-511). A second study addresses the need for thermal protection of ice samples which are returned to Earth; without such protection one might return only a glass of dirty water.

Thanks are due to Dr. Gail Klein of JPL for providing information on the above topics.

A COMETARY TALE

The history of astronomy is replete with the gradual unfolding of knowledge about the structure and function of familiar objects.

The earliest Greek astronomers quite naturally thought that the Sun might be a hot rock or perhaps a container filled with fire. Some sophistication was added to solar-energy theories by Helmholtz when, in the middle of the last century, he hypothesised that the Sun shone through energy released by its slow contraction under the force of gravity.

However, elementary calculations showed that this source of energy would be depleted in approximately 20 million years. Work by Lyell in geology and Darwin in biology indicated that such a relatively brief period of time was inconsistent with other knowledge about the age of the Solar System. The story of how the twentieth-century theory of nuclear energy solved the problem is a fascinating one and not yet complete; the rate of production of neutrinos by the Sun seems to be anomalously low when compared to predictions.

The pattern of the development of a theory is of historical interest, but it can mean more. One might suppose that a retracing of paths of discovery can better equip us to deal with current puzzles. On the eve of the arrival of the international fleet of spacecraft at Comet Halley, it is appropriate to examine the evolution of a few of the ideas about comets.

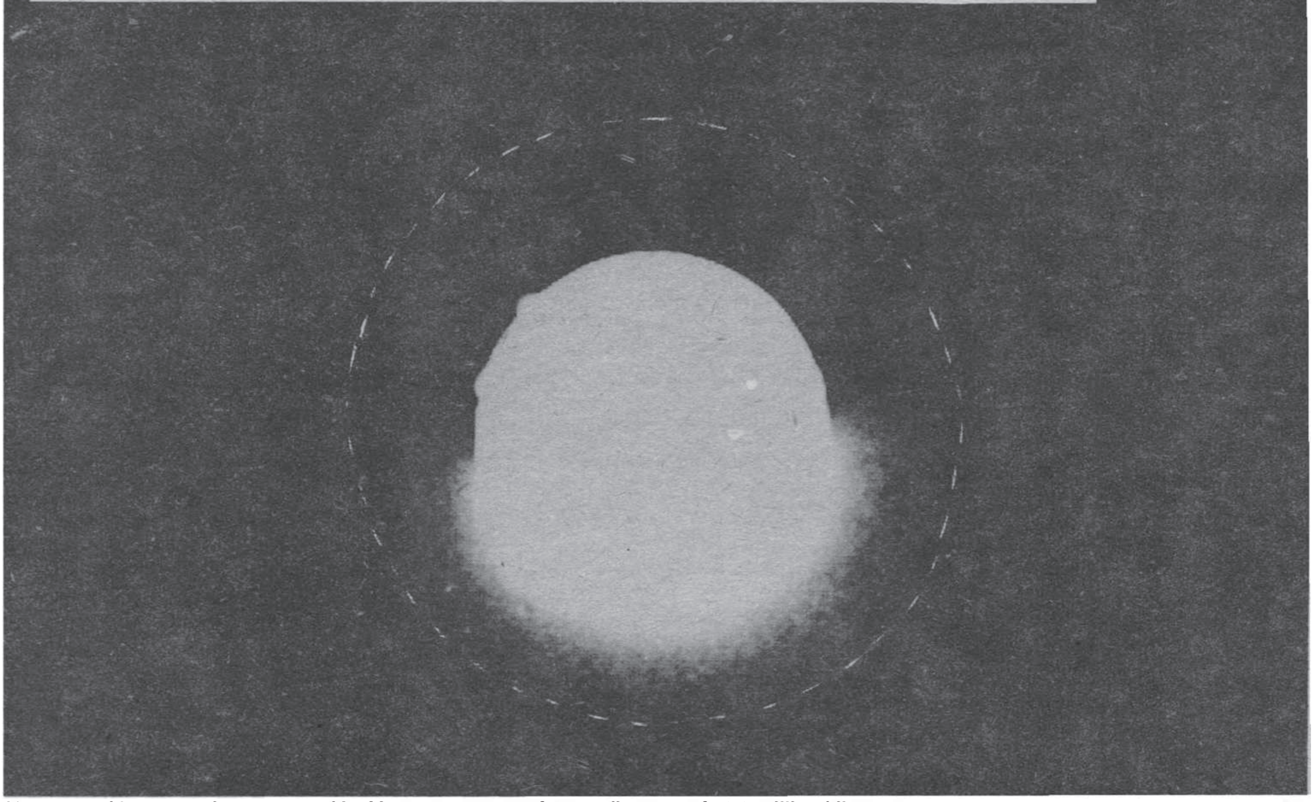
Aristotle, and later Ptolemy, believed that comets were meteorological phenomena, objects of the upper atmosphere. In the sixteenth century the great observational astronomer, Tycho Brahe, demonstrated through careful measurements that comets were too distant to be Earthly phenomena – they must be of celestial origin.

The next major advance was due to Newton who stated that the orbits of the comets must be conic sections: ellipses, parabolas, or hyperbolas. Building upon this dynamical theory, Edmond Halley published in 1705 a list of cometary orbits which he had computed. He noticed that the great comets of 1531, 1607, and 1682 had nearly identical orbits and postulated that they represented one comet travelling in a highly-eccentric ellipse. Halley predicted its reappearance in 1758, and we have been looking forward to visits of his comet ever since.

During the first half of the nineteenth century the German astronomer Johann Encke intensively studied the orbit of the comet which came to bear his name. Encke's comet, with a period of only 3.3 years, was the first short-period comet to be discovered and even now has the shortest period known.

Continued on Page 94.

VOYAGER RETURNS FIRST URANUS PICTURE



Uranus and its outer ring, captured by Voyager cameras from a distance of 73.3 million kilometres. *JPL*

The first clear picture of Uranus was returned by the Voyager 2 spacecraft at the end of November while it was still eight weeks away from the planned close encounter with the giant planet on January 24.

Scientists at the Jet Propulsion Laboratory, Pasadena, California, which has managed the epic Voyager mission to the outer Solar System, used computers to combine six images returned by the spacecraft's narrow angle camera on November 28.

They were taken from a distance of 72.3 million kilometres and clearly show the outer, or epsilon, ring which lies some 51,200 km from the planet's centre. This is the most prominent of Uranus' nine known rings.

Ground-based observations of stellar occultations by the rings have determined that the epsilon ring is eccentric (elliptical) with its widest protion about 100 km wide and its narrowest protion about 20 km. The consequent variation in brightness is discernible in the image.

Various artifacts due to electronic effects and image processing can be seen in the over exposed central protion of the image. Long exposures are made feasible by recent modifications to Voyager 2's attitude control system that were designed to reduce smear-producing spacecraft motions.

Uranus, one of the giants of the Solar System, lies some two billion miles from Earth and can only be seen in our own skies through powerful telescopes.

The planet is tipped on its side giving it a unique rotation and is known to have five moons as well as the nine ring features.

Voyager 2 will pass close to the Uranian moon, Miranda, shortly before its main planetary encounter which takes it within 107,000 km of the planet's centre.

The closest approaches to Uranus and its satellites all occur within five and a half hours, which compares unfavourably with the spacecraft's previous encounters with Jupiter (35 hours) and Saturn (13 days). One reason for this is the unusual axial tilt which places the planet and its moons in one plane relative to Voyager.

But in that short time scientists will obtain more information about Uranus, its satellites and rings than has been learned since Sir William Heschel discovered the planet on March 13, 1781.

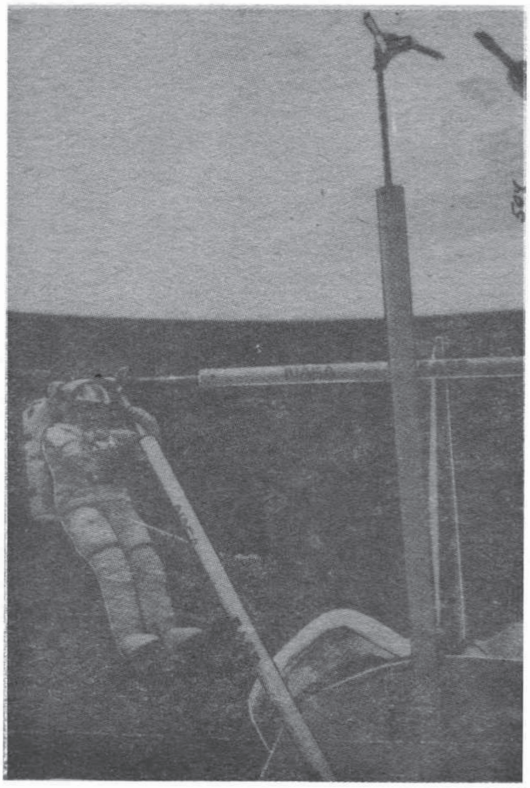
Much of the data collected during the closest approach will be recorded on the spacecraft for playback to Earth on following days.

In addition to two cameras, photopolarimeter and a spacecraft radio, Voyager carries an infrared interferometer/spectrometer and radiometer, an ultraviolet spectrometer, cosmic ray detector, a plasma instrument, a low energy charged particle detector, magnetometers, planetary radio astronomy receiver, and a plasma-wave instrument.

Spaceflight will be providing full coverage, including pictures, of this exciting encounter in forthcoming issues.

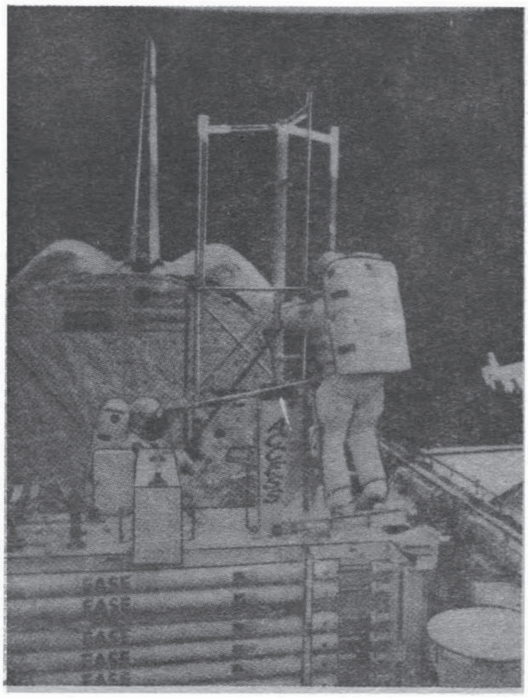
Atlantis Crew Demonstrate Space Assembly Techn

HIGH RISE IN O



An early phase of construction of the EASE pyramid. Ross wears space suit with red stripe.

Starting work – Spring and Ross begin construction. Stowed components in the Orbiter's payload bay can be seen in the foreground.



Anchored to a foot restraint on the manipulator arm Ross works on the ACCESS tower. He is controlled from inside Atlantis by astronaut Mary Cleave.

iques

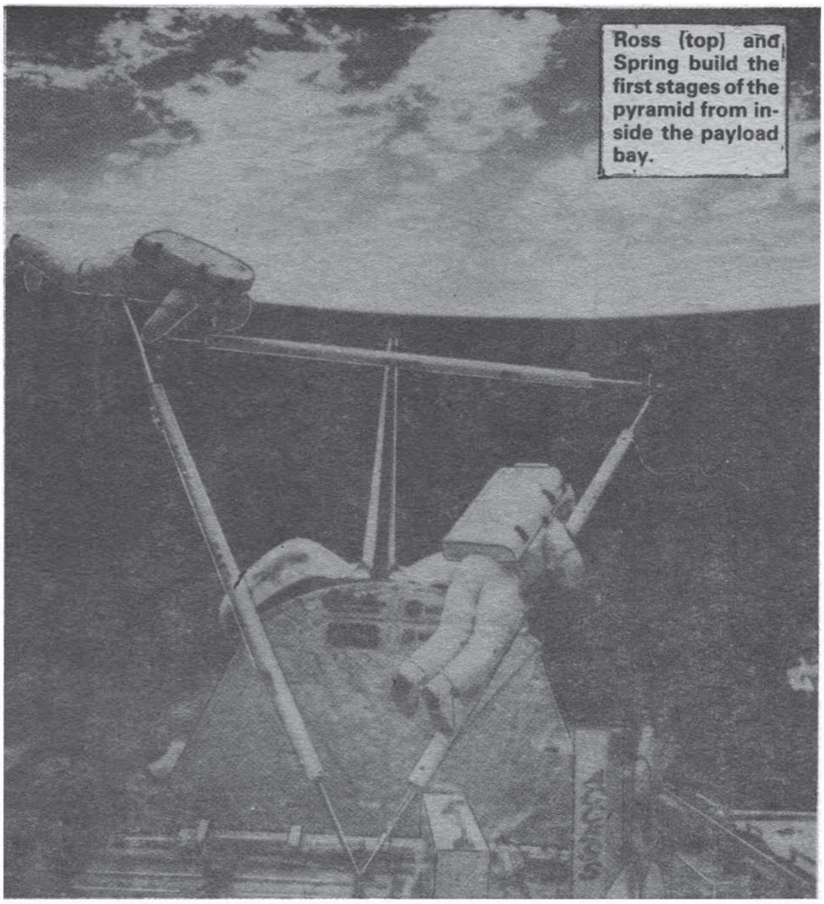
RBIT

These spectacular pictures from Space Shuttle mission 61B show how Man will one day be building his home in Space.

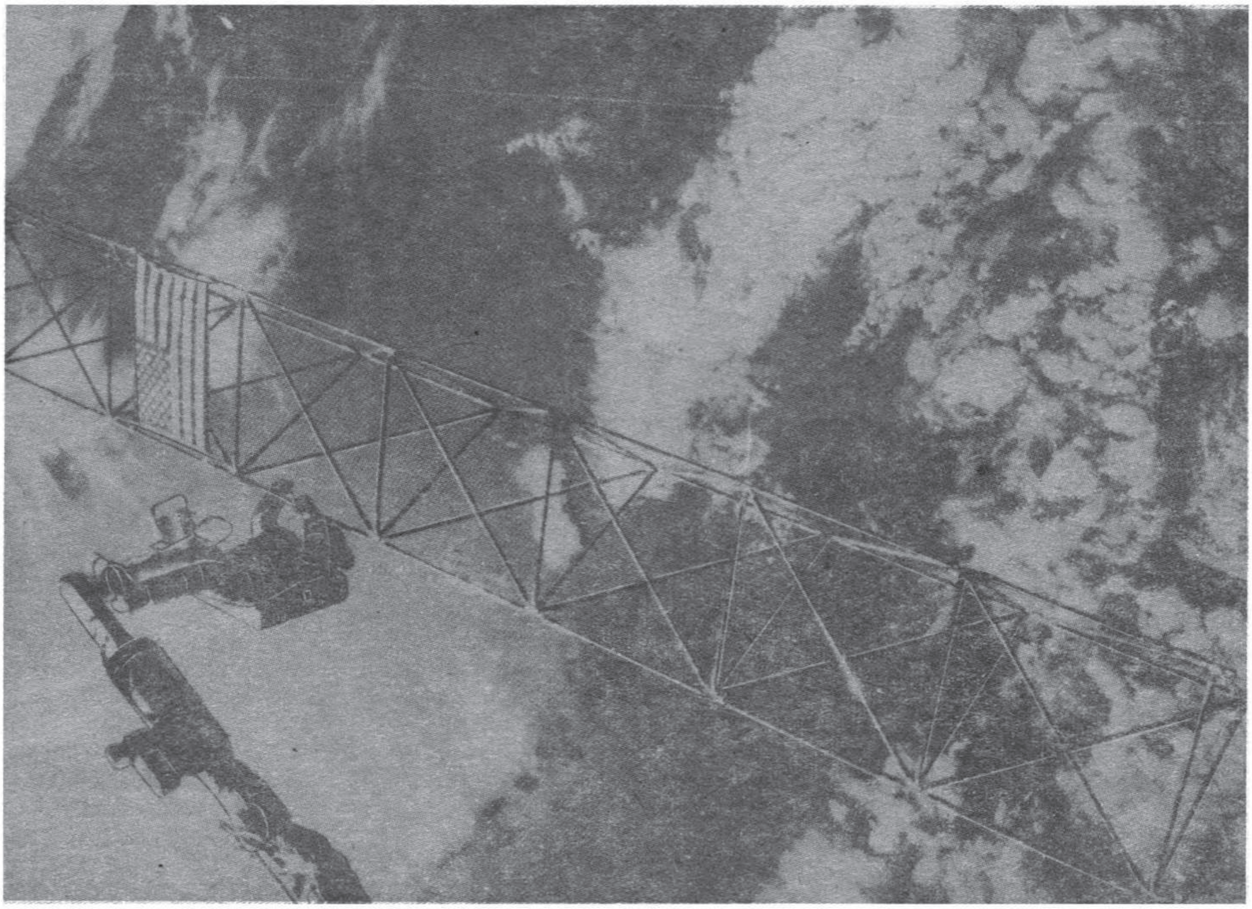
In the first test of its kind astronauts Sherwood Spring and Jerry Ross proved beyond doubt that in the coming decade large space structures will be built in orbit.

During two EVA's lasting a total of more than 11 hours they built a 13.5 m tower (ACCESS) and a 3.6 m pyramid (EASE) several times.

Success of 61B's space construction tasks has provided a key input to the problem of how to plan construction of the Space Station.



Ross (top) and Spring build the first stages of the pyramid from inside the payload bay.



Ross holds the tower extending from the Shuttle's payload bay as he is manoeuvred on the manipulator arm to check the joints.

FLYING FREE

By Keith Wilson

It was like a scene from a science fiction film: an astronaut, silhouetted against the black void of space, hurtled around the Earth at over 32,000 km/h - unattached to his spacecraft. This spectacular feat was made possible because of the Manned Maneuvering Unit (MMU), a £7.5 million jet-powered backpack. The unit's success was largely due to the experience gained by its predecessors, the first of which flew aboard Gemini 9 more than 17 years earlier.

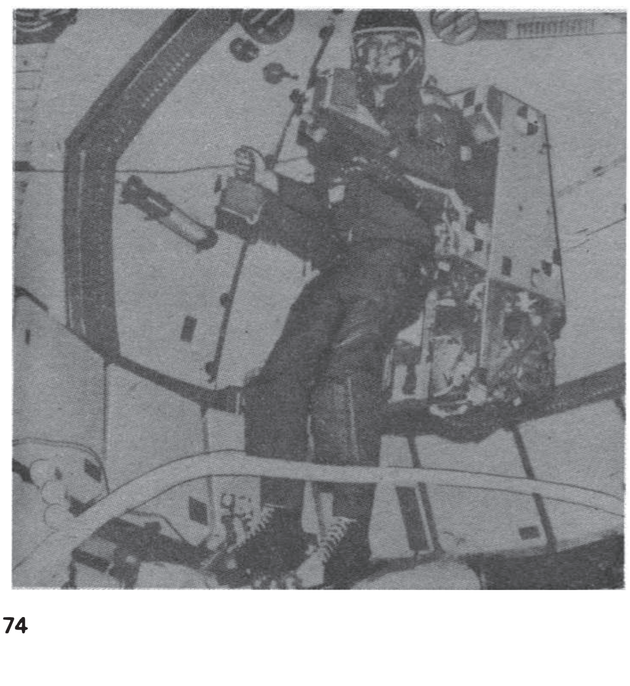
Gemini and the AMU

The first American space walk performed by Ed White during the Gemini 4 mission in June 1965 was a great success and received world-wide coverage. Pictures of White floating majestically in space adorned the covers of magazines and books. However, NASA's plans for future Gemini excursions were even more ambitious. In what was to become NASA's second walk, Gene Cernan would don and fly a device known as an Astronaut Maneuvering Unit (AMU), a powered backpack designed to give the astronaut freedom of movement in space.

The unit was developed by the US Air Force as a Department of Defense Gemini experiment under the leadership of Colonel Daniel McKee of Air Force Systems Command. Project officer was Major Edward Givens, selected as an astronaut a few weeks before Gemini 9. Constructed by Chance Vought, later to become Ling-Temco-Vought, the unit was a rectangular aluminium backpack carrying 12 thrusters mounted on the corners of the framework. Hydrogen peroxide was used as propellant and thruster firings were controlled from two sidearm supports. It carried self-contained life-support, communications, telemetry, propulsion and manual and automatic stabilization systems. The dimensions were: 81 cm high, 56 cm wide and 48 cm deep.

The prime DoD objective was for astronauts to use it in the inspection of satellites and two test flights were planned: by Gene Cernan on Gemini 9 and Buzz Aldrin on the final mission, Gemini 12.

Jack Lousma flies the M509 unit during the Skylab 3 mission in 1973.



The plan called for Cernan to perform a 2.5 hour spacewalk during which he would move to Gemini's adapter section, put on the device and then launch himself into space - but still attached by a tether.

When the space walk took place on 5 June 1966 it did not go according to plan. Inadequate restraints proved to be a problem and Cernan had to struggle with the unit. The arm assemblies were deployed and communications links were attached but Cernan's exertions put a strain on his life-support system and caused his helmet visor to fog. He returned to the cabin, leaving the unit still in the adapter. The failure resulted in a drive for proper restraints and positioning devices for better body control during space walks.

The Skylab Tests

Development of today's MMU can be traced back to 1969, the year when the Martin Marietta Company of Denver, Colorado began developing astronaut manoeuvring technology. It provided two such devices for testing aboard the Skylab space station in 1973/4, the large volume allowing the testing of maneuvering units in zero-g without venturing into open space.

Two versions were included. Experiment M509, a backpack, and Experiment T020, a foot-controlled device. Major C.E. Whitsett of the USAF Space and Missile Systems Office was the principal investigator for the Skylab backpack and the first man to fly the Shuttle MMU, Bruce McCandless was one of two co-investigators. The Skylab version had two configurations. The automatically stabilised model was a backpack unit with 14 fixed thrusters controlled by two hand controllers on extending arms. This was the configuration more favoured by the astronauts - during Skylab it was flown for a total of 14 hours by five astronauts, with and without spacesuits. The second mode used a hand-held device - the same backpack was worn but the astronaut had a handgrip with controls for a pair of thrusters fed from the unit's nitrogen propellant tank by a short hose.

The Shuttle MMU: Features

During the second half of the 1970's Martin Marietta, under a Johnson Space Center contract, began developing a backpack manoeuvring unit for use aboard the Shuttle, then planned for a 1979 maiden flight. Much of the work was based on data produced from the M509 Skylab model; the result was the Manned Maneuvering Unit.

The MMU is an essential element of Shuttle space walks allowing astronauts to operate beyond the confines of the Orbiter's payload bay. This mobility can be used for a wide range of activities: Orbiter inspection, satellite servicing and repair, cargo transfer, satellite retrieval, science investigations and observations, in-space contruction and rescue operations.

Two flight units were accepted by NASA and delivered to Houston in September 1983; a third unit acts as an engineering model. The units cost about $45 million to develop and the cost of a new one is estimated at $10 million.

The unit consists of two side towers and arms connected by a central structure made of aluminium. The towers support some of the thrusters and astronaut displays and contain the unit and space suit retention latches. Also mounted on the towers are two flexible 'lightpipes' that curl in front of the astronaut's helmet and signal when the thrusters are firing.

The centre structure supports two batteries, circuit breakers, control electronics assembly and two nitrogen tanks and propulsion lines. Commands to fire the thrusters come from the rotational and translational hand control-

lers at the ends of the right and left arms, respectively. The arms are adjustable in length and angle. For free-flight they are 30° below horizontal; for worksites 82° below and 102° below for launch storage. They are adjustable over a range of 12.5 cm. Overall, a unit is 125 cm high, 83 cm wide and 121 cm deep with the arms extended; weight is 150 kg fully loaded with 12 kg of propellant. The total weight of a unit and its suited wearer is between 293 and 336 kg.

The propulsion system consists of 24 gaseous nitrogen thrusters with two supply tanks and is divided into two systems. Each system has 12 thrusters and one supply tank but normally the two reservoirs feed one thruster system. However, in the event of a failure, crossfeed valves ensure that a supply is available. The same valves allow the tanks to be recharged from the Orbiter supply and a pressure guage mounted on each unit tower allows the astronaut to monitor his supply. Nitrogen is used because it is non-contaminating and each thruster provides 7.6 N of thrust, the normal speed being 0.6 m/s.

The control electronics are arranged in redundant component sets. Normally both are used but a unit can be run on just one. Three gyros provide positional information and electrical power comes from two 16.8 Vdc silver-zinc batteries that can handle six hours of operations. Three flashing locator lights, visible up to a distance of 1 km, enable an astronaut to be pinpointed from the Orbiter.

Thermal control is achieved by most of the exterior surfaces being painted white; heat rejection from the control electronics assembly is provided by radiator surfaces on the rear panel and upper pressure vessel cover being coated with silvered Teflon. Heaters are bonded directly to some components for both on-orbit storage and operations.

When the units are not in use, Flight Support Systems hold them at the forward end of the payload bay behind the crew compartment. These have adjustable foot restraints to give astronauts the correct height for donning and doffing the units. It is here that the batteries can be recharged and propellant tanks filled - toggle valves on the support systems and in the Orbiter control the supply.

MMU: Operations

To use a manoeuvring unit, a tethered astronaut backs into it, placing his feet in the support system foot restraint. Latches then spring into receptacles on the suit's own backpack; a lap belt is an additional restraint. The tether is then removed and the unit is released from the framework by pulling two levers.

The unit is checked with the astronaut still in the foot restraint. Originally the plan was for the astronaut to remain fixed to a short tether for the first ten minutes of operations but this plan was abandoned in early 1983. During checkout the wearer positions hand controls to test the redundant modes of operation and look for faulty thrusters.

Turning the rotational hand controller on the right arm fires thrusters to move in pitch, yaw and roll. The translation hand controller on the left arm is used for straight line movements - forward, reverse, up, down, left and right. An 'automatic attitude hold' is also available for the three rotational axes by pressing a button on the right hand controller. A fibreoptic cable between the unit and the spacesuit enables operations to be monitored on the spacesuit display and control module on the astronaut's chest. Readouts show propellant quantity, battery power level and any malfunctions. Astronauts working away from the Orbiter can use a ranging aid to guage distance - it is just a calibrated metal rod held at arm's length.

Joe Allen captures the Palapa satellite during mission 51A in November 1984.

At the end of operations, the astronaut reverses into the support framework, shuts down the unit and puts his feet in the foot restraint. By pushing two levers he latches on to the structure and a safety tether is then attached. To disengage, the astronaut pulls release rings on the front of both unit towers, retracting latches from his suit's backpack.

For mission procedures development and crew training, a Space Operations Simulator was developed by Martin Marietta. The simulator provides realistic training in the operation of the unit against full-size satellite mockups as well as portions of the Orbiter. A large-screen video display enables astronauts to practice velocity control to and from an Orbiter.

The installation of two Manned Maneuvering Units in Orbiter *Challenger* for mission 41B took place in the Kennedy Space Center's Orbiter Processing Facility in November 1983. Early in 1984, *Challenger* was in orbit and astronauts were flying free in space for the first time.

Mission 41B

The Shuttle's tenth mission featured two space walks during which MMUs were tested successfully by Bruce McCandless and Bob Stewart - for McCandless it was the climax of many years of work on manoeuvring units.

The first EVA took place on day five of the mission: 7 February 1984. McCandless approached the port support structure and donned MMU-3. Attached to the unit was a 35 mm still camera and a TV camera was positioned on McCandless' helmet. 'Bruce is in free flight,' reported Commander Vance Brand. 'It may have been one small step for Neil but it's a heck of a big leap for me,' said McCandless as the historic event began. Confining his movements to the area above *Challenger*, staying in sight of his colleagues watching through the Orbiter's overhead windows, McCandless moved slowly away to a distance of 45 m before returning. He then moved away again, this time to a distance of 96 m, at all times being tracked by *Challenger's* radar. 'Are you going to want the windows washed or anything while I'm up here?' he asked on his return. McCandless was clearly enjoying the flight, as were the many viewers watching live TV coverage. His only complaint was of, 'shudders and rattles and shakes' when a forward movement was initiated while the attitude-hold mode was engaged.

ASTRONAUTICS AT STOCKHOLM

A record number of people attended the 36th International Astronautical Congress in Sweden last autumn at which more than 500 technical papers were presented. Society delegates Dr. L. R. Shepherd and Mr. L. J. Carter report on the proceedings.

Introduction

Those of us who attended the 36th International Astronautical Congress in Stockholm last October, fully cossetted against the weather, were in for a nice surprise. Hurricane Gloria, whatever it did in North America, brought unseasonably warm weather to Sweden and for a few days boosted temperatures to their highest since the mid-1850s. These pleasant conditions greeted people on their arrival in Stockholm. However, the winter woolies were not transported in vain, since, before the Congress was half-way through, the weather reverted to normal.

Stockholm was founded in 1252 and became the capital of Sweden in 1634. More urgently, in 1967, Sweden converted to right-handed traffic, to the consternation of one of your authors (LJC) who had not been there since before that date!

The Congress attracted a record attendance of 1200 participants, plus over 130 Press representatives. More than 500 technical papers were presented. Although the Congress venue was outside Stockholm this was compensated for by its excellent facilities. The daily journey, made by train from the central station, brought forth the interesting discovery that train announcements in Swedish sound exactly the same as they do in English at BR stations! It also highlighted those who had enjoyed themselves too much the previous evening (promptly dubbed "the leftovers") who were found waiting on the platform, having missed the earlier trains.

Opening Ceremony

The Congress, having the theme of "Peaceful Space and Global Problems of Mankind", was held at the Stockholm Fair (Massan). The language was English though one-way interpretation into French and Russian was offered during the Opening Ceremony. All of the conference rooms were equipped with overhead projectors and remote control slide projectors, with video tape equipment and large TV screens available.

Every one of the 950 seats at the Opening Ceremony was filled. Before the formalities began entertainment was provided by a youthful 40 piece orchestra. Attired in bright pastel-coloured jump-suits, the enthusiastic players presented a swing repertoire at a high acoustic level.

The Opening Ceremony, proper, began with a film from Hassalblad entitled "Echoes of Space", backed up by a computerised slide show (with sound) requiring 15 projectors. This was followed by the more conventional proceedings consisting of several short welcoming speeches and the conveyance of greetings via satellite on behalf of the UN Secretary-General.

A most distinguished note was added by the presence of His Majesty King Carl XVI Gustaf, Patron of the Congress, who, at the conclusion of the Opening Ceremony, toured an adjoining 2000 sq. ft. exhibition area. This featured 42 exhibitors and included the display of a number of satellites, both in full-scale and as models. These comprised Viking, Tele-X, Spot, Columbus, Marecs, Exosat, Giotto, Space Shuttles, Hermes, the NASA Space Station and several versions of the Ariane rocket. Fourteen satellite TV programmes were also shown throughout the duration of the exhibition.

Current Events

The "Current Events" sessions, which have become a regular feature of Congresses, are held in the early evening, immediately following the afternoon technical sessions and invariably attract large audiences. Not only do they provide an occasion to meet those intimately involved in major space projects but offer a rare opportunity to move behind the scenes and gain a unique insight into each event.

The first session of this sort in Stockholm took the form of a discussion between two Soviet Cosmonauts and two American Astronauts. It attracted a packed audience of over 600. Another, held during the evening of Thursday, October 10, was concerned with the latest results from Soviet Interplanetary Vega flights to Venus. The chairman for this fascinating presentation was V. A. Kotelnikov, chairman of the Intercosmos Council.

Dr. Fearn reported it thus:-

"The first speaker was V. L. Barsukov, Director of the Institute of Geochemistry in the USSR, who summarised the 15 Soviet spacecraft which made the journey to Venus, with emphasis on the nine soft landers. Most recently, the Vega 2 lander, in its analysis of rocks at the landing site, obtained data which suggests that Venus may have possessed extensive water oceans around 2.5 billion years ago. On being questioned later about the fate of this water, he surmised that some is now chemically bound within the rocks and soils but that a large proportion has been lost to space.

The talk continued with a description of the synthetic aperture radar data acquired by Veneras 15 and 16. Using this instrument, these spacecraft mapped the northern hemisphere of the planet between 30 degrees and 90 degrees latitude. Features identified included a highland area the size of Australia, surrounded by mountains – 300 to 500 km diameter, circular structures – which may have a volcanic origin, and linear mountain ranges resembling those on Earth resulting from plate tectonic motions. There is some evidence of an expansion in the size of the planet.

The Vega Project, described in detail, placed

emphasis on the deployment of the lander modules and of the balloons used to study atmospheric conditions and circulations. Unfortunately, the landers were able to provide data for only about 15 minutes because communications with Earth were via the fly-by probes, which were correctly positioned to supply this relay service only for that time. Conversely, the experimental packages suspended below the 3.4m diameter helium-filled balloons transmitted directly to radio-telescopes in the USSR, USA, Australia and Europe. This made it possible to track the balloons for 46 hours over a distance of about 12,000 km (9000 km on the night-side of the planet, 3000 km on the day-side). Velocities reached 250 km/hr.

The approach of the USSR spacecraft to Halley's comet will take place at very high velocity so shielding has been provided over sensitive parts of the vehicle. The first scientific data will be acquired over a two to three hour period, two days before closest approach and at a distance of 14 million km. The second session will be undertaken at seven million km distance. The space-craft is intended to pass within 10,000 km of the nucleus of the comet.

Additional information on Veneras 15 and 16 was pro-vided by an excellent film, although the commentary was, unfortunately, in Russian. However, the final speaker Dr. V.M. Balebanov, deputy director of the Institute for Space Research, gave further clarification by presenting preliminary temperature and pressure measurements obtained from the balloon experiments and mentioned that some atmospheric turbulence has been detected; velocities were measured to within 1 m/sec. Besides the rapid longitudinal motion of the balloons, a slow polar drift was observed. The lightning flashes seen on earlier missions were also detected."

Social Occasions

The main social occasions was a Smorgasbord reception put on by the City of Stockholm at the City Hall for everyone connected with the Congress, including the registered participants and all those concerned in supporting roles. A total of 1200 people turned up at the Blue Room, where the event was held, and where a most convivial evening was enjoyed.

A programme of tours was arranged to various space industries and scientific institutions in Sweden but, as all were located relatively far from Stockholm, they occupied the full day of Wednesday, October 9, notwithstanding the fact that technical sessions were scheduled for that morning.

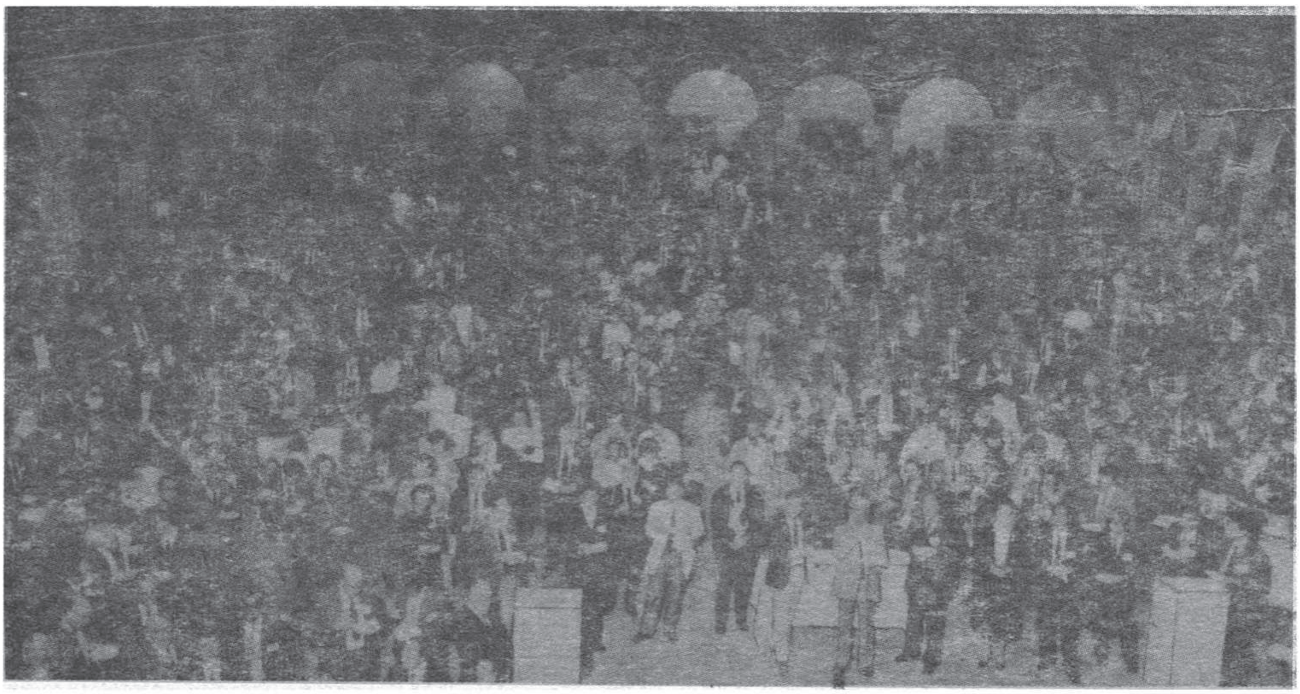
One of the more modest excursions involved retracing our steps from space ships to a ship of an earlier time, the Wasa, launched (and sunk) in 1628 and rescued from a watery grave only in recent times. Whatever might be said about her worthiness as a ship, her rating as a work of art was undeniable. The carving was exquisite and the hulk, of which a very large part had been preserved, fascinating in design and preservation. A detour to the Kaknastornet nearby, a tower which is one of Stockholm's most popular tourist attractions, was less successful. Mist had closed in to such an extent that the visibility was almost nil.

A technical tour to Kiruna and Esrange, although involving an extra cost of 1600 Swedish Kroner (about £140) and an 8.30 am start, was planned for 40 but over-subscribed to reach 60. This was too many for the connecting flight but the Swedish Air Force very kindly flew in an airacraft to take the excess. It included a visit to a Lapp Museum before moving to Esrange to look at the data collection and launch facilities. Unfortunately, there was no sign of the Northern Lights.

Daily Journal

Six issues of an eight-page A4 size 'Daily Journal" appeared during the Congress, the first issue being ready to welcome delegates on arrival and including a message from His Majesty King Carl XVI Gustaf. Subsequent issues contained a selection of news about Congress activities and prepared articles on aspects likely to interest delegates, e.g. Eureca, the Swedish Viking Project, SETI, etc., the final issue carrying an interview with Dr. Shepherd (designated Professor, but with name mis-spelled, for the occasion) happily, paying credit to the fact that he attended the very first Congress at Paris in 1950 when the IAF was first discussed. It mentioned his many contributions to the

Reception at the 36th Astronautical Congress in Sweden.



IAF, including holding the office of President in 1957 and 1962, and Vice-President over many more years, as well as substantial participation in committee work and attendance at Academy meetings. Incidentally, there were just 22 participants at the 1950 Paris meeting though only a few years later the number had reached several hundred and now looks set to exceed the thousand mark regularly.

Business Sessions

The business sessions were unusually rapid, most of the detailed work now being delegated to the Bureau and the many standing-committees. Eighteen new organisations were admitted to the Federation, including two UK businesses, British Aerospace (Space & Communications Division) and Logica. Our congratulations go to both. These bring total IAF membership to 89, a rate of growth that will support not only the Federation's financial development but also its scientific and technical activities. Most of the organisations joining the IAF, nowadays, are governmental space agencies and industrial firms involved in space activities. These are able to afford subscriptions which are substantially higher than those paid by most of the national astronautical societies that made up the earlier membership. The finances of the Federation have benefitted considerably as a result. This has made it desirable to change the status of membership of such bodies, to reflect their importance to the IAF.

One proposal is that membership grades be simplified into Voting Members and Regular Members, with the proviso that Voting Members should be neither commercial nor international organisations.

No change was proposed for the registration fees payable for the 37th Congress to be held at Innsbruck during the period October 4-10, 1986, (field trips on October 11). Sixty-two Sessions will be held, with the Wednesday wholly devoted to technical sessions and all excursions taking place on the final Saturday. An invitation from the BIS to hold the 1987 Congress at Brighton was accepted. For future years, Bangalore, India, for 1988 and Beijing, China, for 1989, have been agreed. Invitations had also arrived from Israel and Yugoslavia.

Besides formal relationships with international organisations such as the UN, and with international non-governmental organisations, such as ICSU, COSPAR, etc., the IAF cooperates with many other bodies having space interests. One such organisation, recently formed, is the Association of Space Explorers, whose membership is limited to those who have flown in space. This group of astronauts and cosmonauts is seeking some form of affiliation with the IAF and IAA.

The Business Sessions concluded with the presentation of a certificate made out to each Member Organisation, all of which had been flown on the latest Shuttle flight.

Gordon Bolton receives his Fellowship certificate from Dr. George Mueller (right), IAA president.

Committee

The IAF now has a large number of Standing Committees which meet during the Congresses. In fact, since these involve a rather high proportion of the Congress participants, the meetings now clash seriously with the lecture sessions. To reduce this conflict of interests, it was proposed that the Saturday and Sunday immediately preceeding the Official Opening of the Congress should be set aside for committee meetings. This new departure will be tried out in Innsbruck at the 1986 Congress and, assuming a satisfactory outcome, the necessary arrangements are being made to follow the practice in 1987 at Brighton.

The work of the IAF (and IAA) technical committees is largely concerned with the organising of the symposia which make up the lecture sessions of the Congresses and, to a lesser extent, in organising symposia outside the framework of the Congresses. This is an important function because these symposia not only highlight the latest work in progress in space science and technology but also expose new areas that merit study and encourage serious speculation and conjecture about longer term developments. Without such scientific conjecture there would be a danger of stagnation and sterility in future space technology and it is an important function of the IAF and, of course, its members societies to provide the forums for the discussions of these vital issues.

The members of committees are appointed and to this extent attendance is limited to those selected, unlike the lecture sessions. Nevertheless, the transactions have to be properly reported to the IAF General Assembly, i.e to the member societies or institutions. Little purpose would be served, however, in attempting to summarise the proceedings of most of the committees except for the few cases which are highlighted in the presentations to the General Assembly. One such meeting was that of the Education Committtee.

Education

There was a large turn-out of the education committee, reflecting IAF interests in this area. The first item of business concerned altered terms of reference for the Frank J. Malina Award, to recognise educators active in the field, bearing in mind that there were already awards for graduate and undergraduate papers. Malina Awards take the form of medals, i.e they do not carry any stipends or travel funds. (Note to BIS members: nominations for recipients may be made, in the first instance, to the BIS, who will then forward them to the IAF for evaluation).

Technical Sessions

It is impossible to describe fully the numerous wide-ranging technical sessions so, as before, we propose to reproduce a selection from some of the sessions to give an idea of what occurred.

INTERSTELLAR TRAVEL

IAF Technical Session

L. R. Forward stated interstellar travels would be realised in large starships (or worldships) travelling with relatively small velocities, a small percentage of the velocity of light, during many hundreds and thousands of years, propelled by nuclear energy/nuclear pulse rockets, laser and ion beams or matter-antimatter annihilation.

Interstellar hydrogen would be collected to use as an energy source and jet mass. An interstellar probe could be sent during the life of our generation, claimed Forward.

A. Bond and A.R. Martin developed their earlier concept, project Daedalus, a two stage nuclear pluse rocket employing deuterium and helium-3 as fuel, collected in Jupiter's atmosphere.

The interstellar flight to Barnard's Star would take about 50 years and a 500 tonne payload would disperse many sub-probes prior to the stellar encounter. They would collect data on planetary systems, transmitting it back to Earth. It follows from that paper that simple interstellar missions are possible.

J. Tarter presented papers with D.C. Black and J. Billingham on the methods of the detection of extra solar planetary systems: direct detection and indirect detection: astrometric, spectroscopic and photometric. Various methods would be suitable for particular masses and orbital parameters of the orbits.

G. Vulpetti described the anti-matter/annihilation/ propulsion in the Earth-space, interplanetary and interstellar flights, annihilation thruster design concepts, and compared antimatter-based engines with the conventional ones.

The annihilation offers the highest yield of conversion of mass into kinetic energy and antiproton-nucleon system exhibits the highest energy density. But it would need to solve very difficult problems such as antihydrogen production, storage, control and costs!

Mieczyslaw Subotowicz

SOLAR SYSTEM EXPLORATION

IAF Technical Session

Nine papers were presented this year ranging from the long-term thinking of Dr L. Friedman, who forsees an extra-terrestrial future for mankind with the placing of a manned colony on Mars, to the more down to Earth (or at least near-Earth) wishes of Dr Arshinkov of Rumania who has developed a technique for the precision measurement of spacecraft magnetic fields and the means to compensate for these, thus improving the resolution of magnetometers.

The overall standard was high, with papers well prepared and well presented. Some deserve particular attention as they brought new information. Most interesting was a paper on the Giacobinni-Zinner encounter by J.C. Brandt of the NASA Goddard Spaceflight Center and the Vega missions to Venus, presented by Drs Gogoschev and Barsakov of the USSR, a close second.

The comet paper described the first results of the encounter between the International Cometary Explorer (ICE) and comet Giacobini-Zinner. The ICE spacecraft, originally ISEE-3, was, by a combination of clever orbital dynamics and navigation, removed from its orbit at the L1 libration point and re-targeted, via the magneto-tail, to encounter Giacobini-Zinner. This re-targeting involved many Lunar fly-by's to alter the spacecraft trajectory and many months of patient calculation waiting for the right moment for the final adjustment into the encounter path but the effort was amply rewarded by results, which showed that Alven's comet model, developed in 1957, was largely valid and that the comet was a more active body than had been thought. The most surprising results were the spatial extent of the energetic heavy ion flux, the unexpected crossing of the neutral sheet separating the two plasma lobes and the amount of turbulence in the connecting interaction region.

Papers on the Vega missions described techniques used to place the lander on the surface of Venus and release a balloon which floated in the atmosphere and which carried instrumentation for analysis of the atmospheric constituents, density and pressure. The descriptions of the balloon testing, the techniques for entry into the Venusian atmosphere with aerobraking, parachute deployment and finally balloon inflation were of particular interest.

Scientific results obtained by the lander were presented by Dr Barsakov who described the findings on the soil composition and the techniques by which the samples were obtained.

The other current planetary mission, the Voyager mission to the outer planets, was covered by Dr R. Lester who described techniques to be used to return data when Voyager encountered Uranus in January 1986 and Neptune in August 1989. This mission stretches the limit of the technology of radio frequency transmission of data, needing extensive ground arrays to intercept such weak signals. The technique for image motion compensation, using tape recorder speed modulation, was also described.

Papers on the future aims of NASA and ESA included description of the Comet Rendezvous and Asteroid Fly-by mission (CRAF) proposed by JPL, and the Joint ESA/NASA Cassini mission, were presented by R. Draper of JPS who is currently the Project Manager of the Mariner MK2 Planetary Bus which NASA is building for the purpose of flying such deep space missions at an affordable price.

Another paper in the class of "Future Missions" came from Dr Balabanov, who described a proposed Phobos mission to Mars and international collaboration in the mission. It will be launched in 1988 and make wide-ranging scientific studies. Practically all aspects of planetary science will be addressed from the upper atmosphere to below the surface.

Last but not least Dr Fredga of the Swedish Board for Space Activities presented a paper on the Swedish Viking Mission to be launched "piggy-back" with the French Spot spacecraft. "Piggy-back„ is perhaps an understatement as the Viking spacecraft, which weighs about 500 kg, must carry the Spot which weighs about 2000 kg. This mission will provide detailed magnetospheric science in the Sun-synchronous elliptic orbit which is timed to overfly the Swedish ground tracking stations in Kiruna during most of its useful orbital life.

It was an interesting symposium with new ideas, new interests and plenty of enthusiasm.

Gordon Whitcomb

ORBIT TRANSFER VEHICLES

IAF Technical Session

A survey of upper stages, existing and under development, devoted to the STS, was presented by J.P.Loftus of NASA, JSC, emphasising the trend towads reusable and space-based upper stages. The author addressed the advantages of three-burn strategies, aerobraking and aero-manoeuvring strategies and the need for on-orbit propellant transfer (already accomplished for storable, under development for cryogenic propellants).

The paper of E. Bangsund (Boeing) reported on the seven years of the IUS development effort, especially the achievement of the high reliability standard and the possible impacts on test and design philosophies for OTVs in the 1990's.

The next paper dealt with the development status of the OSC's upper stages, the solid propellant TOS (6.1 tonnes GTO, scheduled for 1986) and the bi-liquid propellant AMS (2.5 tonnes GTO). As highlighted by the paper of F. van Rensselaer (OSC), it is a modular building-block system

covering the range from the PAM D capabilities up to the IUS (for the TOS/AMS with 3 tonne GEO, scheduled for 1988). The Centaur-class capability could be reached (4.5 tonne GEO), with a new turbopump fed engine in the AMS.

The paper of A. Hankins (Aerojet) described a Liquid Propulsion Module (LPM) with a turbopump fed engine. The 'Transtar', with a 16.7 kN thrust, will allow a considerable reduction in Shuttle launch costs through its high specific impulse, (328 sec) and its lightweight tanks. By adding the LPM to the IUS, payloads of 3.9-4.5 tonnes could be injected into GEO. A 1988 launch might be possible.

A survey paper on the (US) Orbital Manoeuvering Vehicle (OMV) was given by I. Bekey of NASA-HQ. The fully reusable OMV, remotely controlled and based either on Shuttle and/or Space Station, will considerably extend the reach of both parent craft (eg altitude changes up to 2,700 km, and plane changes up to 7.5°). The OMV, to be ready in 1990/91, is intended to place and retrieve satellites, to perform reboost and deboost manoeuvres and, in particular, to serve as the operational manoeuvring vehicle in the vicinity of the Space Station.

A paper by W. Kleinau (MBB/ERNO) presented a survey on Orbital Transfer and Servicing Vehicle (OTSV) studies in Europe. Regarding integrated and modular OTSV options, the recent studies tend to favour a modular, unmanned OTSV as requested for the Columbus-IOC. A promising candidate appears to be an OTSV with 1.6 tonnes of bipropellant (MMH, MON) with a cluster of 4 x 400 N pressure fed transfer engines (leaving space for a centrally-mounted docking mechanism).

D.E.Charhut of General Dynamics discussed in his paper 'Space Based Orbital Transfer Vehicle (OTV)' the results of a recent study. Although the expendable Centaur G may be a baseline for a ground-based OTV, the future OTV will look quite different. It will be a full reusable, cryogenic (LOX/LH_2) and Space Station-based modular spacecraft. The key features will be the applications of high energy cryogenic propulsion, lightweight structure (thin-walled tanks, space-basing design), propellant saving by aerobraking/manoeuvring and advanced engines. IOC should be possible in the mid-1990's.

T. Tanabe of the University of Tokyo presented an interesting discussion on the problems of OTV operations. In his paper, 'OTV-Network', a network of fuel stations at different positions (altitude and inclination) was described. This network would allow flexible operation of space-based OTVs and would improve, considerably, the launch capability by separate launching of spacecraft and propellant. Low-cost tanker and propellant launchers are required for the supply of the stations and a schedule management/control centre. It is expected that for ≥ 25 missions/year the OTV-Network would become cost effective.

A. Fester of Martin Marietta addressed the key question of bringing large quantities of propellants to the Space Station in order to support its operations and those of the OMV and OTV. For 1991-2000 there will be a requirement for 115 tonnes/year of LOX/LH_2 and about 10 tonnes/year of MMH/NO_2O_4 or N_2H_4 storable propellants. Two transportation methods have been studied.

1. Transportation by manifested tank-module flights (14 -25 tonne cryogenic propellants per mission), requiring nine flights with Shuttle per year.
2. Scavenging of unused STS-propellant. With cryogenic propellants an ET/Aft Cargo Carrier with a tank capacity of 3-12 tonne/mission could be used, requiring about 16 flights with Shuttle per year. For bi-propellants, and OMS-scavenging tank system of 7 tonne capacity could be installed for a greater number of flights. An economic strategy is to combine manifested tanker and scavenging flights, for example to provide six (shared) tanker missions and eight scavenging missions per year, resulting in delivery cost to the Space Station of some $600-900 kg for cryogenic propellants.

W. Kleinau

LIFESAVING ROCKETS

IAF Technical Session

The history symposium opened with a memoir paper by H. A. Boushey, a retired USAF General, on the first United States JATO (Jet Assisted Take Off) flight test that took place from March Field in California during August 1941. Three flights, flown by General Boushey himself, used a rack of six solid fuel rockets, each with a thrust of 12.8 kg, mounted beneath a small, single seater Ercoup aircraft. The flight tests were successful, but it is interesting to note that the solid fuel rockets, developed by CalTech, sometimes suffered from what were euphamistically known at "blows". These were explosions of the rocket caused by internal pressure build up as a result of incorrect burning which could be caused by, for example, imperfections in the rocket charge. This problem was also encountered by British workers in the late 1930's during their development of solid fuel barrage rockets for Anti-aircraft defences.

The most important paper at the symposium was presented by V. P. Michailov from the National Committee for the History of Science and Technology at the USSR Academy of Sciences in Moscow. Michailov is a recognised expert on the history of lifesaving rockets and his paper entitled "Lifesaving Rocket Development in the 19th and early 20th Century" spread new light on the early history of such devices. Existing scholarship implies that, although some work had been carried out in France at the end of the 18th Century, the development of the use of rockets for ship to shore rescue really began in England with the work of, among others, Trengrouse who was testing his systems early in the 19th Century. However Michailov, from the study of documents in his possession, has now come up with definite proof that a Frenchman, Ducarne-Blangy, developed and successfully tested his form of life saving rocket in 1799. This new information is of great interest to rocket historians and further papers from V. P. Michailov on the subject will be eagerly awaited.

Other presentations of note included survey papers by A. Schnapf (Aeospace System Engineering in the USA) on "25 Years of Meteorological and Environmental Satellites" and by S. Fries (NASA History Office) on the "Evolution of the Concept of the Space Station.

E. J. Becklake

EUROPE STEALS DBS LEAD

IAF Technical Session

One whole session was devoted to direct broadcast satellites and related technologies. It is paradoxical that, although direct broadcast is one of the natural applications of satellites and indeed one that brooks no terrestrial competition, it is the slowest application to get started. In the United States, it can even be said to be languishing.

One of the papers presented was a comprehensive report on the state of all the US systems which can best be described as going nowhere rapidly. In truth, it seems as if direct broadcast will occur in the United States via a route never intended. That is, by the enthusiastic and enterprising public acquiring receive only terminals, with antennas as large as three metres, principally to receive signals not intended for their use. The costs are often ten times or more as high as would be necessary if adequately powered DBS satellites at the right frequencies were used. Despite this public enthusiasm, the financial community continues to hang on to the notion that the idea is not competitive and is reluctant to help in the financing. This reluctance, of course, implements a self-fulfilling prophecy.

At the same time in Europe, through the French and German programmes, the Radio Television Luxemburg programmes, and the Swedish programmes Tele-X and

Nordsat, slowly but surely DBS is being put into effect. These programmes were reported on during the session. This European head start over the US is paradoxical too, inasmuch as the economic advantages of satellite over terrestrial methods are less there than in the United States because of the higher population densities.

It was interesting to receive rare but welcome reports on the Soviet systems and to note that they are changing from the original UHF frequencies with few channels to S-Band and ultimately to K-Band with the full number of available channels. This is consistent with the rest of the world's practice. Technical data on their satellites were made available to a greater extent than previously.

Several important technology papers were delivered, including one excellent account on the results of propagation in the 20 and 30 GHz range done in East Germany, and an important paper on eclipse simulation tests for a 200 watt travelling wave tube amplifier from Nippon Electric in Japan.

The session was interesting and important and still leaves everyone mystified by the slow progress in this natural application of satellites.

Wilbur L. Pritchard

CETI-SETI

IAF Technical Session

This session was unusual because among the speakers were a bishop and a journalist.

Bishop K. Stendahl of Stockholm stated that God is above the Universe and the possible discovery of ETI will change nothing. It will increase only the glory of God. He claimed there is no conflict between religion, faith and science despite the Bible not being a scientific text.

Journalist, N.N. Nelson, was interested in the diplomatic, political and press consequences of the possible discovery of ETI signals. It should be subject to proper international law and plans made on how to inform people throughout the world should contact ever be made.

More routine were other papers. H.P. Klein discussed general principles behind the Viking search for life on Mars and expressed a view towards examining practical approaches to the resumption of such studies on Mars for possible extraterrestrial life.

In his review paper A. Hjalmarson stated that nearly 70 interstellar and/or circumstellar molecules are known today, the heaviest one, $HC_{11}N$, containing 13 atoms. Discovery of the organic abiotic molecules in the interstellar medium is important for the origin of life and our knowledge about the formation of the complex molecules.

J. Billingham reported the results of the Science Workshop on the Evolution of Complex Life. It had investigated factors governing biological evolution and emergence of complex living organisms depending on large scale cosmic events in space and on the planet, such as supernovae or passage of the Solar System through a spiral arm of the Galaxy or the striking of the Earth by an asteroid.

R. E. Davies tried to prove that possible panspermia in the Universe should be investigated, whilst P. J. Hall discussed the role of three important principles, those of Copernicus, Mach and Anthropic, as well as the uniformity of physical laws throughout the cosmos, in their ability to explain the origin of extraterrestrial life.

J. Tarter explained how to look for and explain the observed noises exceeding the noise level predicted on the basis of a Gaussian model and M. D. Papagiannis postulated the multi-path approach for SETI, including alternative concepts and search strategies to attract a larger number of scientists.

M.J. Klein reported the first results of the NASA SETI sky survey field test at Goldstone using the 26 m antenna, and A. Betz analysed the possibility of detecting SETI signals in the infrared range. The 1 MeV transmitter of 10 m diameter receiving signals on the wave length 10 um, would have the range of about 50 parsecs.

S. Gorgolewski proposed to look for ETI in the range of very low frequency, about 1 kHz. and M. Subotowicz proposed another "We are alone!" solution to the Fermi paradox, accepting that the extraterrestrial civilisations – if they exist – are terrestrial-like in their energy output. They cannot send isotropic beacons and therefore are non-communicative. This is a more optimistic conclusion than "We are alone!", but more pessimistic than the acceptance of the existence of Dyson or even Kardashev type civilisations. He concluded that we should build more and more sensitive radio telescopes.

Mieczyslaw Subotowicz

INTERNATIONAL SPACE STATION

IAF Technical Session

The Space Station is now the subject of intense study not only in the US but also in Europe, Canada, Japan and of course in a more hardware oriented way in Russia. The European efforts are being harmonised by ESA, generally in the form of Columbus and its elements, although France is active in other Space transportation areas such as Hermes.

Four main sessions were organised as part of the Space Station Symposium within IAF and were concerned with Design (nine papers), Technologies (nine papers), Operations (seven papers) and Utilisation (nine papers). The contributions were thoroughly international attracting papers from Europe, US, Canada, Russia and Japan, and included papers from ESA, NASA, DFVLR and CNES.

Although all were interesting and generally well presented there was a feeling to those involved in the overview of current studies that there was not a lot of new material being offered. This is perhaps to be expected because intense efforts are being made to finalise as far as practicable the concepts for the Space Station and Columbus elements. When concepts are reasonably frozen, then we may expect to see how the detailed ideas are developing in each of the four main areas.

The overall symposium co-ordinators were Bob Freitag, a leading NASA Space Station man since the outset and A. S. Eliseev of the Intercosmos Council of the USSR Academy of Sciences. The session Chairman and rapporteurs were selected from leading figures in Space Station work in Europe, US and Japan.

In the design session the most progressive papers came from Japan which appears to be quite clear in its objective of proposing a dedicated experiment module and is moving quickly towards the module definition.

ESA provided an overview of Space Transportation Systems as well as an account of the system planning to achieve Columbus. The European Retrievable Carrier (Eureca) was presented in some detail. As well as providing an update of the US Space Station Programme, NASA included a good paper on analysis for the Space Station Common Modules. This work is of direct relevance to Europe.

The Canadian contribution dealt with a Space Construction and Servicing Systems Design for the Space Station era, showing the benefit of spectacular achievements with the Remote Manipulator System operating on the Shuttle. On a truly European note a French paper dealt with the alternative means of achieving a Manned Space Station launched and assembled with European Vehicles.

In hindsight, one should not be surprised at an apparent lack of innovation at this critical and frantically busy time for the major space companies, it is a period of concept freezing and consolidation. Corresponding sessions to be held at the 37th IAF Congress should be able to give a more positive view of what is being proposed.

I. V. Franklin

THE FIRST 25 YEARS

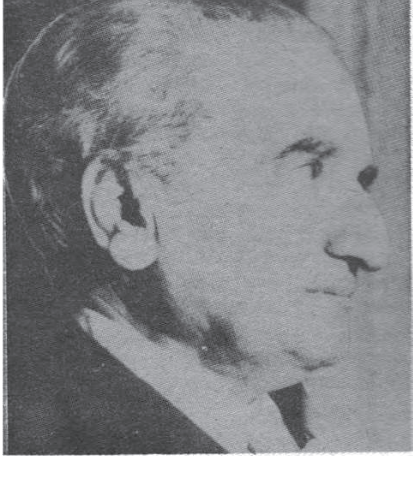
The IAA celebrated its 25th anniversary in Stockholm on October 5, 1985 with a symposium held under the auspices of the Royal Swedish Academy of Sciences. A quarter of a century previously the foundation of the IAA was confirmed at the 11th International Astronautical Congress, which also took place in Stockholm.

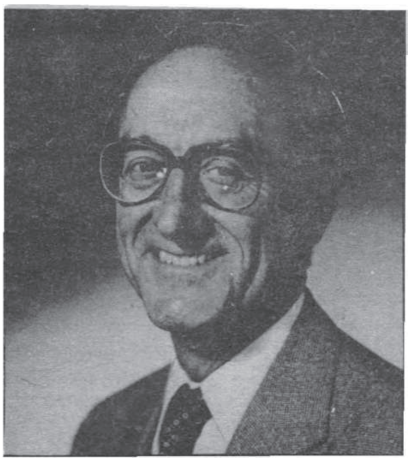
The International Academy of Astronautics, which is colloquially referred to as 'the Academy', was founded by a Resolution of the General Assembly then called the Council of the International Astronautical Federation (IAF) in September 1959 at its 10th International Astronautical Congress in London. The eminent aerodynamicist Theodore von Karman was appointed to be its first Director and was invited to form a Founding Committee with the task of setting up an initial membership and drafting its Statutes. The original members of the Academy numbered 45 and about a half of these were present at the 11th International Astronautical Congress in Stockholm in August 1960 when the IAF Council accepted the proposed Statutes and thereby confirmed the foundation of the IAA.

The IAA is devoted to fostering the development of astonautics for peaceful purposes, recognising individuals who have distinguished themselves in a branch of science or technology related to astronautics. The Academy organises international symposia both within the framework of the International Astronautical Congress and at other times. Besides the proceedings of its meetings, it produces the journal, Acta Astronautica, and has also issued an astronautical multi-lingual dictionary in seven languages.

The IAA was directed by von Karman until his death in March 1963, when there was a short succession by Frank Malina, one of the two Deputy Directors of the Academy. At the 2nd Regular meeting of the Academy at the 14th Congress in Paris 1963 the title of Director was changed to President and the Deputy Directors became Vice-Presidents. Malina did not wish to stand for any of these offices and Dr Charles Stark Draper, the distinguished pioneer of the technology of Inertial Guidance, accepted the Presidency of the Academy. Dr Stark Draper held office for 20 years before handing over to Dr George E. Mueller, distinguished for his direction of the Apollo Project, who is now pursuing a policy of expansion of the Academy.

Theodore Von Karman (1881-1963), first President of the Academy.





Dr. George E. Mueller, IAA president who is pursuing a policy of expansion of the Academy.

Appropriately, the 25th anniversary of the Academy was celebrated this year at the 36th International Astronautical Congress in Stockholm, the place of its foundation, with a short Symposium held on the evening of Sunday October 5th at the Headquarters of the Royal Swedish Academy of Sciences and under their auspices the Symposium was followed by a Reception given by the President of the Swedish Academy. The papers presented at the Symposium described the history and work of the IAA with, in addition, one devoted to the history of the Royal Swedish Academy.

The Academy

The IAA is governed by a Board of Trustees consisting of the President and four Vice-Presidents, each responsible for a particular aspect of the Academy activity, namely: Awards & Membership; Finance; Scientific Programmes; and Publications, together with four Trustees in each of the four Sections. The affairs of the Academy are run by this board and by the various administrative and scientific committees.

Academy membership is divided into four sections:

(i) Basic Sciences;
(ii) Engineering Sciences;
(iii) Life Sciences, and
(iv) Social Sciences.

The last section was recently introduced to recognise those concerned with the impact of space science and technology upon society and who have made considerable contributions to astronautics in such areas as management, communicatory education, economics and other social aspects.

SOCIETY NOMINEES ELECTED TO IAA

New Academy elections in Stockholm brought its membership to 700 Members and Corresponding Members, representing a total of 39 nations.

Academy elections for 1985 included several Nobel Prize and Lenin Prize winners, and more than 50 leaders from COSPAR to the Basic Sciences Section. Over 30 Engineering Executives were elected from major aerospace companies in the USA, Italy, France, the UK and Germany, while the Life Sciences elected key personalities in the field of Manned Spaceflight. The new Social Sciences Section expanded its membership with the addition of new individuals in the fields of history, commerce, sociology, management and economics.

The BIS congratulates all who were successfully elected to the Academy, including those nominated by the Society, who are listed below. We also congratulate the many BIS Fellows, nominated from other sources, whose applications were successful for example, Wernher Buedeler, Tom Paine, Frederick Ordway, George James and Arthur Slotkin.

The BIS is also happy to extend congratulations to Professor Reimar Lust, Director General of ESA, on receiving the Theodore von Karman Award from the IAA for 'sustained contributions to the advancement of space science and technology and the peaceful uses of outer space'. Professor Lust, a physicist by profession, has been closely connected with European space activities since the very early days. He was the first Scientific Director of the European Space Research Organisation (ESRO), one of the precursors of ESA, from 1962-1964, and sat on various ESRO committees until 1972. He initiated many space experiments, in particular the so-called Barium cloud experiments in the upper atmosphere. Before joining ESA, he was President of the Max-Planck-Gesellschaft, an organisation of 55 research institutes and 10,000 employees in Germany.

The following persons, nominated by the Society, have been elected to the Academy:

Dr. David Baker, Managing Director of Space Consultants International, is already well known as a frequent Spaceflight contributor. He is author of six books, two of which "History of Manned Spaceflight" and "The Rocket" are major contributions to the literature, and his output to date includes over two hundred publications of a technical and semi-technical nature.

In 1965-67, Dr. Baker was engaged in mission evaluation for Gemini studies, specialising in rendezvous and docking. This was followed by Apollo mission studies (including extended Lunar exploration) as well as mission planning for post-Apollo programmes.

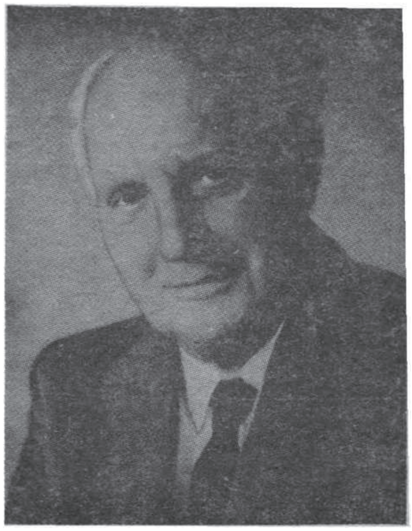
The years 1970-74 saw him at work on planning and operations analyses for space transportation systems (Shuttle, space tug and recoverable expendable launchers) followed by future space project evaluation i.e. anticipated satellite and space programme development across a twenty-year projection.

Currently, he is undertaking technical analyses of global space projects.

Gordon R. Bolton is Manager of Sustaining Engineering Division, Manned and Retrievable Systems Department at ESTEC, and Engineering Manager responsible for the ESA Spacelab Project which flew on the Shuttle in 1983, a post which won him the NASA Public Service Medal in 1984. From 1967-1973 he was Engineering Supervisor at Lockheed, Houston one of several posts held after leaving UKAEA at Winfrith.

Leonard James Carter joined the pre-war BIS. In 1945, when several of the members met to reform the Society, he volunteered his services and was immediately recruited as Secretary, on an honorary basis. In 1953 he became the first appointed Executive Secretary, responsible for the administration of the Society, an office which he has filled ever since.

Today, the BIS flourishes and is an acknowledged leader amongst the astronautical societies of the World. The biggest single factor in ensuring its stability and firm basis has been the considerable organising skill and business acumen of its Executive Secretary and the dedication which he shares with his staff. In addition to the normal administration of the BIS Headquarters, Mr. Carter has been managing editor of its publications and has played an important part in establishing them in the forefront of astronautical literature.



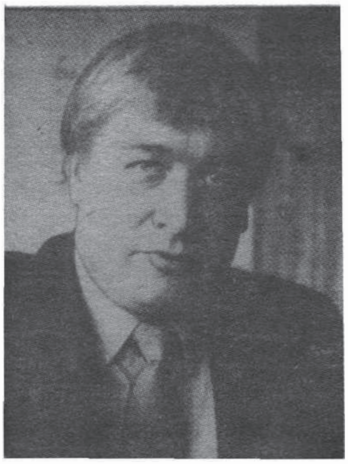
P. E. Cleator

Philip Ellaby Cleator not only founded the BIS and steered it through its early days but published numerous articles on space travel in both UK and foreign magazines during the 1930s, including his book "Rockets Through Space", which appeared in 1936 and influenced many who subsequently became prominent space exponents

Some of his experiences of those early days are due to appear in a "Space History" issue of the JBIS shortly. This will also contain a detailed biography of his interesting life.

Peter James Conchie, is now Director of Business Development at British Aerospace, Space and Communications Division, after a career going back to the late 50's and early 60's when he was involved (at Hawker Siddeley) in the Blue Streak/ELDO programme. He was responsible for the assembly, integration test and launch of the first ESRO satellite, ESRO II, and Project Manager of ESRO IV, subsequently becoming Chief Project Manager (communications satellites), responsible for OTS, Marot, Marecs and ECS.

He is now responsible in initiating and leading studies relating to the UK proposals for free-flying co-orbiting and polar platforms as part of the European contribution to the US Manned Space Station, as well as the UK proposal for a new single-stage to orbit launch vehicles (HOTOL) for low Earth orbit, via stages to geostationary orbit.



Dr. D. Dale

Dr. Derek Dale was Senior Scientific Officer/Principal Scientific Officer at MOD from 1968-1974, before moving to ESA to become Head of New Scientific Projects and to become responsible for all preparatory activities for such programmes. On completion of his work on the SSL1 mission Dr. Dale became leader of the Giotto Mission Definition Study and is now Giotto Project Manager at ESTEC.

In 1977 he became Project Manager for the Spacelab Simulation mission know as ASSESS II which used dedicated flights on a NASA research spacecraft to simulate the scientific operations of a Spacelab mission. On completion of the ASSESS II mission he became Head of Future Projects in the Scientific Directorate and was responsible for the preparation for approval of Hipparcos, the Infra Red Observatory (ISO) and Giotto. Following approval of Giotto in the summer of 1980 he was appointed Project Manager.

Dr. John Keith Davies, currently Research Fellow at the Department of Space Research, University of Birmingham, carried out the search for moving objects in data returned by the IRAS Satellite, leading to the discovery of six new comets, three asteroids and the previously unknown 70 m tail on Comet Tempel-2. Much of this work has already been reported in the pages of the Society's magazines.

Currently, Dr. Davies is engaged on development work for the ROSAT (Extreme Ultra-Violet Telescope).

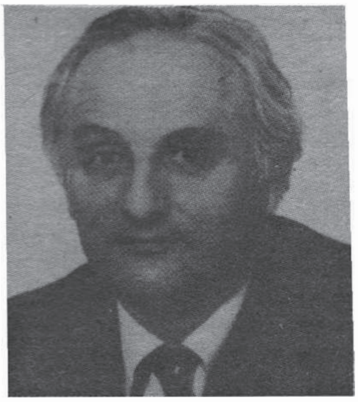
Peter Leslie Victor Hickman is Divisional Managing Director, British Aerospace Dynamics Group, but his career goes back to 1959-1964 when he was Assistant Chief Dynamicist (later Chief Dynamicist, Space Projects) at Hawker Siddeley Dynamics, later becoming Projects Manager for the TD1 and TD2 satellites. In due course, he became Chief Project Manager (Satellites) for the Company, moving up to Group Director and Managing Director in 1980.

Other distinctions include Past-Chairman of the United Kingdom Industrial Space Committee and past member of the Astronomy, Space and Radio Board of the SRC.

He was awarded the OBE in 1983.

Dr. John Theodore Houghton, Director General of the Meteorological Office, has been engaged in space science experiments for over twenty years now. He was a Principal Investigator for experiments on the Nimbus 4, 5, 6 and 7 satellites, co-investigator on the Pioneer Venus Orbiter Missions and is author of many publications on remote sensing of the Earth's atmosphere.

Dr. Houghton has long been involved in the management and organisation of UK space science activities. During 1979-



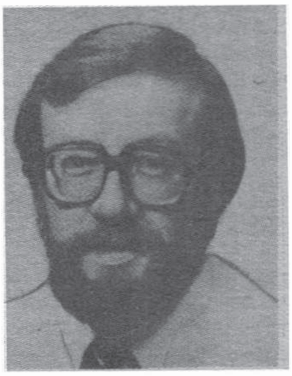
Dr. J. T. Houghton

1983 he was on Secondment as Director of the Appleton Laboratory and, from 1981-1983, Deputy Director of the Rutherford Appleton Laboratory. From 1976-1978 he was President of the Royal Meteorological Society, in 1982 Chairman of the Earth Observation Advisory Committee of ESA and from 1981-1984 Chairman of the Joint Scientific Committee, World Climate Research Programme.

A. K. Jefferis

Alan Kenneth Jefferis is Chief Executive Satellite Systems, British Telecom International. During 1982-3 he was seconded as Managing Director, United Satellites Ltd., a joint company set up by British Telecom, British Aerospace and the General Electric Company, to establish a UK DBS satellite system.

His long career includes contributions to the UK technical input to the design of the complete communication system and satellites from INTELSAT I (1965) to INTELSAT VI (currently under construction), as well as to the development of the EUTELSAT system as Chairman of the Technical Committee of that body from inception in 1978 to 1982. He was recenlty nominated as visiting Professor on Satellite Communications at the University of Surrey.



Dr. A. R. Martin

Dr. Anthony Robert Martin is already well known to members both as a former Vice-President of the Society and

as the Editor of the Interstellar Studies issues of JBIS. Now Section Leader, Ion Source and Neutral Beam Development Group of UKAEA, Culham, he has carried out extensive numerical and experimental work on plasma flow around satellites. In fact, he carried out the first work in the UK on rare gas ion engines and has continued development of ion sources to date.

His output to the professional literature on interstellar studies already totals about thirty papers.

Dr. D. Edgar Page is Head of the Space Science Department of the European Space Agency at ESTEC, a post he has occupied from 1975 to date. For a decade before then he was Head of the Cosmic Ray Division, Space Science Department of ESRO and the author of numerous contributions to space science literature.

Dr. R. C. Parkinson

Dr. Robert Charles Parkinson has contributed to nearly every facet of space transportation and propulsion, including cryogenic liquid rockets, solid rocket propulsion, propellant formulation, electric propulsion, etc., for over twenty years.

From 1965-1981 he was at the Rocket Propulsion Establishment at Westcott, first in the Liquids and then in the Solids Division. From 1981-1982 he was Superintendent, Propellants I Branch at PERME, joining British Aerospace in 1982 as Study Manager. For the past two years he was responsible for the Phase A design of the British Aerospace Space Platform concept and of studies which led to the HOTOL vehicle.

He is a member of the BIS Council and contributes numerous far-seeing papers on lunar operations, missions to Mars, etc.

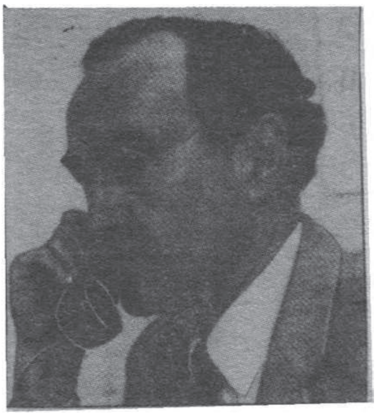
Dr. Michael J. Rycroft is Head of the Atmospheric Sciences Division of the British Antarctic Survey, responsible for 50 staff both in the UK and at two British bases in Antarctica, as well as a member of many international committees concerned with space science and with Solar-Terrestrial physics.

From 1976-1979 he was a lecturer at the University of Southampton concerned with Very Low Frequency Radio Signals, interrupted by a one year period when he was visiting Professor in the Department of Physics at the University of Houston, undertaking researach in ionosphere-magnetosphere-coupling.

To date, he is the author (or co-author) of over eighty scientific papers and reports concerned with atmospheric and space sciences.

Dr. David John Shapland is Head of ESA's Astronaut Office responsible for Spacelab/Eureca Promotion and Use, receiving the NASA Group Achievement Award in 1977 and 1984. From 1955-1960 he was Head of Aerophysics Group at A. V. Roe, moving to America to become Senior Advanced Systems Engineer at Lockheed Missiles and Space Corporation, before returning to ESA in Paris in 1971 to work on Spacelab design and user co-ordination.

He is author of over 50 contributions to the literature.



Dr. D. J. Shapland

William H. Stephens' career began at the Royal Aircraft Establishment, Farnborough. From 1943-47 he was Assistant Director at the UK scientific Mission in Washington. Returning to RAE, he went on to become Head of the Guided Weapons Department before leaving in 1957. In 1959 he become Director General of Ballistic Missiles at the Ministry of Aviation and, in this capacity, was responsible for the development of Blue Streak and its adoption as the basis for the ELDO launcher.

Between 1962 and 1969 Dr. Stephens was Technical Director of ELDO. When the UK withdrew from ELDO he was seconded to the Foreign Office and stationed at the UK Embassy at Washington where his responsibilities included liason with NASA and DOD. From 1973 he has been Senior Executive Director of GT Systems Limited.

In 1961 Dr. Stephens was made a Companion of the Most Honourable Order of the Bath. He has been a Fellow of the BIS since 1952 and received the Society's Bronze Medal in 1972.

D. E. B. Wilkins

David Edward Burnell Wilkins is Head of Spacecraft Operations Division, ESOC, after twenty-one years experience as an engineering manager in the space field. He was Head of the teams responsible for the design and integration of the ESOC Satellite Control Centre in Belgium, and the similar Centre, SIRO-2, in Italy, before managing the studies leading to the establishment of ESOC.

From 1963-1965 he was Manager of the NASA Manned Spaceflight Network Engineering and Training Centre at Wallops Island, followed by five years as Manager of the Project Gemini (later Project Apollo) Tracking Station at Grand Canary Island.

Since 1975 he has been responsible, as the ESA Flight Operations Director, for the successful Mission Control of eleven spacecraft, including METEOSAT I and METEOSAT 2. He has received two Awards from NASA and two from ESA in recognition of his work.

Compiled by L. J. Carter

GIOTTO REHEARSES ENCOUNTER

A final "dress rehearsal" for Giotto will take place just a few days before the spacecraft is due to encounter Comet Halley around midnight on March 13.

The rehearsal will be the last in a series of simulations of the encounter by the European Space Operations Centre (ESOC) which began on October 14 and 15.

Results of the first test last October showed that both the spacecraft and its payload were working satisfactorily. In addition it helped experimentors and engineers involved in the project to gain a better insight into the type of situations they may have to face on March 13.

All scientific instruments have already been switched on and tested. The two Plasma Analysers and the Ion Mass Spectrometer have produced measurements of the solar wind and its composition, and the Magnetometer of the interplanetary magnetic field.

Important observations have been made by the on-board camera of the star Vega, the planet Jupiter and, on October 18 and 23, of our planet Earth. Taken from a distance of about 20 million kilometres, the images, of the Pacific Ocean region show a pattern of brighter and darker structures, the brighter structures being associated with cloud formations. The quality and resolution of the images show that the camera is functioning according to specification.

COMETARY GLITTER

Soviet scientists reported a change in the luminous radiation of Halley's comet during continuous observations throughout last year.

In the summer its luminescence went up by several thousands times compared to that of the previous February, making it equal to stars of tenth magnitude.

Between August and October the intensification of the glitter, the origin of which is still to be studied in depth, slowed down dramatically.

It is currently believed that the glitter phenomenon depends directly on changes in the cometary atmosphere as it approaches the Sun from the depths of space.

TELESCOPIC HELP

A specialised telescope at the international observatory on La Palma has played a crucial role in ensuring a successful Giotto mission.

The Carlsberg Automatic Meridian Circle (CAMC) has been measuring the positions of over 300 reference stars enabling controllers to plot a more accurate course for the spacecraft

Position of the comet is determined by measuring its location in relation to the known positions of the background stars as it moves in front of them. The accuracy of the comet's position is therefore dependent on the background reference stars.

Those stars appearing behind the comet during the last few crucial weeks prior to encounter were not known accurately until the CAMC was set to work. This information has now been passed on to ESA.

SUN REVIVES HALLEY TWIST

The brightness of Comet Halley has fluctuated from night to night, according to ground-based observations with some of the world's most powerful telescopes.

Astronomers were surprised to record the strong variation in brightness from one night to another and now believe the cause to be the irregular shape of the cometary nucleus.

Observations towards the end of last year from the Kitt Peak Observatory, Arizona, showed the icy nucleus to be twisting and turning as it reacted to an increasing influence from the Sun.

It was noted that the quality of observations from the ground depended on which way the comet had turned between viewing periods.

Measurements of vapour streaming from the core confirmed that the dominant material is ice and much of the cloud surrounding and trailing from the nucleus is water vapour

HALLEY'S ROCK

The Daily Mail of October 29, 1985, referring unromantically to "Halley's Rock" — about the size of Manhattan Island — places it 124 million miles away and, according to a Dr. James Gibson using the 60 inch telescope at Mount Palomar, "It's extraordinarly bright, much brighter than we expected it to be at this distance. As it now stands, the comet's gas and dust cloud measures 90,000 miles across."

MiSSED OUT

The next chance to see Halley's comet will be the year 2061, with the comet reaching perihelion on July 28. That will be its 31st recorded apparition.

HALLEY'S COMET ION TAIL

The Giotto mission contains an experiment to detect the influence of Halley's comet on its local environment.

This, the Johnstone Plasma Analyser, was developed by the Mullard Space Science Laboratory of University College, London, and contains a sensor powered by miniaturised, lightweight, high voltage unit built by Cambridge Consultants Ltd.

The instrument will be used to measure the velocity distribution of positive ions near the comet and thus observe the formation of the plasma tail. It has two sensors and a data processing unit. The experiment was tried out on September 8, 1985, while the space craft was transmitting at a high data transfer rate. Full operating voltages were reached and no problems emerged. The instrument was then run for the rest of the week at a lower data transfer rate and has been operating at this rate for two hours every second day.

FIRST DAY COVERS

A special set of stamps is issued by the post office on February 18 to commemorate the return of Comet Halley, and in honour of the occasion the British Interplanetary Society has commissioned its own specially designed First Day Cover and postmark.

The cover depicts in full colour a picture of Edmund Halley together with an artist's impression of the encounter between Giotto and the comet. The illustrations are set out below the inscription 'Halley's Comet Interceptor' and the specially styled Giotto motif.

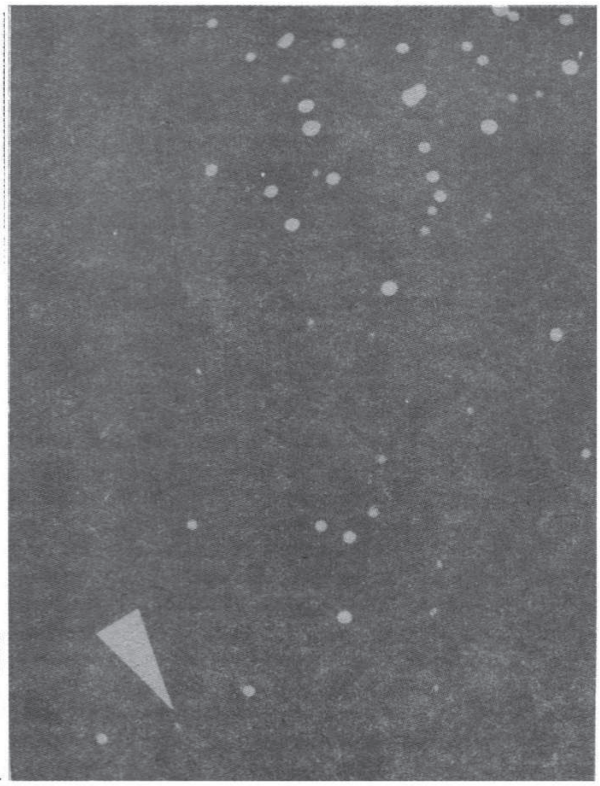
The special postmark incorporates the BIS logo and will be used only on the day of issue, February 18.

Covers are available with a single 22p stamp depicting Giotto entering the comet's tail, or with the full set of four stamps.

To complement the BIS First Day Cover a souvenir version will also be produced incorporating the British Aeorspace emblem and the 22p stamp. It will be cancelled by hand on March 13, 1986 inscribed "Encounter Day"

Details of availability and prices will be advised to all members shortly.

Set of commemorative stamps issued on February 18, 1986 to mark the return of Halley's comet.



HALLEY EXPOSED!

Just visible with a minute tail is this picture of Halley's comet as it tracked through the constellation of Taurus beneath the Pleaides star cluster (top right).

The ten minute exposure was taken by BIS Fellow Douglas Arnold on November 15 beginning at 21.13 GMT.

Camera was a Nikon F3 fitted with a Nikkor f3.5 400mm ED lens and mounted on an equitorially driven telescope. Film was hypersensitised Kodak Technical Pan 2415 developed in D19 developer at 68 degress F for four minutes.

The image above is an enlarged section of the original negative.

Review

Comet Halley: Once in a Lifetime

M. Littmann and D. K. Yeomans, American Chemical Society, 1155 Sixteenth Street, N.W., Washington, D.C. 20036, USA, 1985, 175pp $15.95

On February 9, 1986 Comet Halley will reach its perihelion (closest approach to the Sun) 54.5 million miles. It will then be travelling at 34 miles per second. Gases will boil from the comet's nucleus at the rate of one million tonnes a day but, even so, the comet — with an estimated mass of one trillion tonnes — contains enough ice to endure at least a thousand more passages by the Sun.

Those who seek a book about it which is easy to read and yet authorative, need look no further. This book describes the history which has lead to our present understanding of comets and emphasises the contribution of Edmund Halley, who worked for 18 years to prove that comets obey the laws of physics and travel in orbit around the Sun.

It is a fascinating story and one that can be told and retold without becoming tiresome. The author suggests that Uranus and Neptune, too, are enormous ice balls — having great similarity with comets and may be akin to overgrown comets themselves, with Uranus, Neptune and the comets forming together in this part of the Solar System.

CORRESPONDENCE

A Visit to HQ

Sir, In October last, I finally got around to visiting the "new" British Interplanetary Society Headquarters. I must say that the physical plant, artifacts, library, etc., are most impressive. The wonderful collection of archival material, memorabilia, etc., besides being a priceless resource for scholars and other visitors, imbue the Headquarters with an intimate and unique air of space flight and rocket technology.

My old acquaintance Len Carter showed me around the place. The indefatigable Len has done wonders over the years, managing, coordinating and planning, and acting as a factotum for innumerable chores and requests. May I congratulate Len, his staff and the Journal mastheaders for doing a pioneering and superb job of selling "space" with resources which, I dare say, are meager compared to those available to some of our huge US organisations.

Similarly the Journal offers what those of us who helped in some measure to advance the "space age" are really looking for: that is, imaginative if not provocative articles and projections on space flight. I hope you will continue in this vein and even expand into trans-solar system schemes.

KURT STEHLING
Maryland, USA

Ed. *Members, both from the UK and overseas, who have visited our offices, have been impressed with the magnitude of the task we undertake and have given us great encouragement in our endeavours.*

Soviet Shuttle

Sir, In July/August issue, Alan Parfitt writes of his analysis of the postulated new generation of Soviet launchers. His calculations show that the Soviet heavy shuttle, if comparable in size with the US Shuttle, could indeed have the 95,000 lb payload to low orbit that the US Defense Department claimed in the 1983 publication *Soviet Military Power*.

This increase of 50 per cent over the US Shuttle payload is achieved, according to Mr. Parfitt, by the absence of main engines aboard the Soviet shuttle, which accounts for the extra payload availability. Mr. Parfitt ignores the fact that even though these engines are not aboard the Shuttle, they are to be brought into orbit along with the Shuttle, as part of the external tank, and thus their considerable weight cannot be ignored. Furthermore, the DoD estimated payload of the Soviet shuttle has been downgraded from 95,000 lb to 60,000 lb in the latest DoD report, bringing it into line with the US Shuttle capability.

DoD reports of the Soviet shuttle being drop tested from a Mya-4 Bison bomber are being questioned, as the Bison has insufficient cargo capacity to carry the weight of a full-size shuttle.

Finally, reported lift-off thrusts of the three new launch vehicles are inconsistent with Mr. Parfitt's conclusion that the larger vehicles will use the medium lift launcher as a strap-on. The DoD and Mr. Parfitt report that the medium lift vehicle has a thrust of 600,000 kg. Multiplying this figure by four (for four strap-ons for the shuttle) gives a core thrust for the shuttle of 600,000 kg. Applying the same formula to the heavy lift vehicle (for six strap-ons) gives a core thrust of 400,000 kg. As the core is supposedly the same for both vehicles, this casts doubt on the accuracy of these reports.

DAVID ANDERMAN
California

Comet Wine

Sir, At one time, the arrival of a bright comet usually terrified the population but one notable exception was the comet of 1811, considered by the wine growers throughout Europe as particularly beneficial. This comet was one of the most imposing to appear, with a coma diameter of nearly 1 million km and probably the largest known. It also became known as 'The Wine Comet' since the wine that year was superb in quality and quantity, in contrast to that of previous years when it had been so bad that, in the case of the year 1805, for example, its acidity even damaged the wine casks!

Through the association of an exceptional comet and marvellous wine, the 1811 vintage became a legend, depicted in drawings and songs for years afterwards.

The memory of the comet is still recalled at Champagne in France. It takes the form of a design of a star and a pencil of rays on some of the corks and labels used, and may even appear on the boundary gates of vinyards. The arms of the Verzy commune for example, depicts two comets, those of 1811 and 1858, for the latter was also a good vintage year, though hopes raised with the appearances of a bright comet in 1853 were dashed, according to a contemporary cartoon, which shows two wine growers encircling an enormous cask with the caption 'I have drawn this cask believing that the 1853 comet would bring a large quantity of wine. I would have been better off with an umbrella. It brought a lot of water.'

Unfortunately, the appearance of Halley's comet in 1759, 1835 and 1910 did not correspond to exceptionally good wine harvests and there is not much enthusiasm for 1986 either.

A.T. LAWTON
Shepperton, Middlesex

Bacterial Spores and Panspermia

Sir, Recent evidence suggests that life may have existed on the Earth over 3800 million years (Myr) ago. Such early presence implies that only some 200-400 Myr were available after the cooling of the Earth's crust for the chemical evolution of complex life forms, thus life might have arisen through processes involving either non-terrestrial chemical evolution (cosmochemistry) or even the transportation of biological material from another solar system (panspermia).

Dr. P. Weber and Professor J.M. Greenberg of the University of Leiden have reported studies [1] on the survival of biological material in a simulated interstellar environment which place constraints on the conditions required for the survival of life forms in space as proposed in the hypothesis of panspermia.

Four fundamental processes have to be considered for a workable theory of panspermia. Firstly the biological material has to be removed to space after being lifted from the host planet's surface to high altitude. Secondly, it must be transported from one planetary system to another. Thirdly, it has to survive the exposure to the

harsh conditions of interstellar space for the duration of the transportation process and finally it has to be deposited safely on to the new host planet's atmosphere and surface. One proposed mechanism for the interstellar transportation process involves solar radiation pressure as a driving force for the movement of life forms such as bacterial sports but such mechanism may not be satisfactory since an opposing radiation pressure would also act to prevent a small particle from entering the environs of another star. Furthermore, unless shielded in some way, micro-organisms being transported can expect to be readily killed by exposure to the extreme solar ultraviolet radiation environment above the Earth's atmosphere.

As an alternative transportation mechanism, Weber and Greenberg suggest that the random motion of interstellar dense molecular clouds travelling at speeds of around 10 km/s could account for the movement of life forms such as bacterial spores. Based on an estimate of 1 star in 1000 possessing a solar system, survival times in the interstellar medium of 1-10 Myr were indicated for the transportation of the spore from one solar system to another.

In order to provide data, the viability of spores of the bacterium *Bacillus subtilis* were studied after exposure to a simulated interstellar space environment. These are highly suited to viability tests as they are resistant to ultra-high vacuum exposure. By exposing the spores to a UV radiation flux some 10 million times greater than that found in interstellar space, exposure times corresponding to several thousands of years could be readily simulated over a short time in the laboratory.

Survival data from the studies confirmed previous reports that at room temperature UV radiation damage to the spores was greater under conditions of high vacuum than at normal atmospheric pressure. However, at the estimated temperature of a spore in interstellar space (10 K, or -263°C) high vacuum UV radiation damage was found to be remarkably less than that at room temperature. This reduced sensitivity at low temperature might be due to the inhibition of diffusion of long-lived radicals produced by the UV radiation, thereby resulting in less damage to the spore's DNA and proteins. From the viability data, exposure to UV radiation corresponding to approximately 150 years in interstellar space was found to inactivate 10% of the spores and approximately 2500 years to inactivate 99.9% of the spores.

Whilst such survival times are too short to accommodate a theory of panspermia, in a dense molecular cloud attentuation of the UV radiation reaching the spore may be expected by the gradual accumulation of a mantle of molecules around the spore. To investigate this possibility, Weber and Greenberg artificially coated spores with a mixture of simple molecules known to occur in molecular clouds (water, methane, ammonia and carbon monoxide) and studied their viability after exposure to UV radiation. Thin mantles (0.5 μm and above) were indeed found to decrease the sensitivity of the spores by a factor of 10. Since during the passage of such a coated spore through space the molecules forming the mantle would be irradiated for a considerable time, more complex molecules will be photochemically produced. These can be expected to absorb UV radiation more strongly, thereby giving rise to additional shielding of the spore. Further, in the case of a spore located at the centre of a dense molecular cloud with a radius of 1 parsec, allowing for the presence of internal UV sources, the interstellar UV flux reaching the spore is estimated to be attenuated by a factor of around 10,000 or more. Combining these effects, Weber and Greenberg estimate that exposure times of between 4.5 Myr and 45 Myr will be required to inactivate 90% of spores present in a dense molecular cloud of such a size.

Within interstellar molecular clouds, survival times significantly greater than the time required to transport a spore from one solar system to another may thus be attained and thereby facilitate the second and third processes of panspermia already described. However, in order to survive the lethal solar UV environment in the close proximity of either the Earth or a similar planet, during ejection from and deposition onto the planet's surface, attenuation factors at least, 10,000 times greater those than necessary for the case of survival in the interstellar medium are estimated to be required.

Whilst Weber and Greenberg suggest that the coating of a spore with a 0.0 μm thick mantle of material with an imaginary index of refraction of 0.5 would afford this degree of protection, the possible mechanisms by which the spore could be coated with such material and blown into space are still uncertain.

DR. M.J.F. FOWLER
Winchester

REFERENCE

1. *Nature*, **316**, 403-407, 1985.

BIS GUESTS AT 'SPACEWORKS'

BIS representatives attended the Opening Ceremony of "Spaceworks" – the astronomy and space exhibition which was opened at the National Maritime Museum on November 13 by H.R.H. The Duke of Edinburgh, a trustee of the Museum.

The exhibition, open to the public until the end of 1986, is supported by British Aerospace and Senior representatives of BAe at the ceremony included Hugh Metcalfe, Stuart Rothery, Peter Hickman and Peter Conchie. Jack Leeming, Cliffe Nicholas and Alastair MacDonald represented DTI. NASA was represented by Phil Culbertson, Associate Administrator for the Space Station. Other distinguished guests included two of the British astronauts, Professor Jack Meadows, Ray Munday, Roy Gibson and Dr. David Hughes.

Professor Malin, Carole Stott, Alec Boxenburgh and Janet Dudley represented the RGO. Dr. John Becklake represented the Science Museum while Frank Holland (Director of the Piano Museum) was present to support the analogy that astronomy from the ground is rather like playing only the five middle notes on a piano!

Guests were free to tour the 500 sq m exhibition area which not only features astronomy but also many space applications, ending with a large model of the proposed Space Station. Those interested in Halley's comet will be particularly intrigued by the inclusion of an illuminated photographic plate of a star field. The object of the exercise is to guess which of the tiny smudges is actually the comet, the answer being found by pressing a button – at which point a small circle appears to ring the comet.

Spaceworks

The National Maritime Museum, Greenwich, 1985, 95pp, £2.95.

Besides the revolution they have created in science and technology, satellites have become a routine part of our daily life, making possible television programmes such as 'Live Aid', cheap inter-continental telephone calls, global weather maps, safe navigation and so on.

But how do they get up there, why are they needed and where do they go next? These are some of the questions answered in Spaceworks.

After setting the scene with a lightning tour of the Universe, the book explains in straight forward language and with many illustrations how satellites are designed and launched into orbit, the commercial and scientific uses to which they are put and some of the exciting developments in the near future.

The book was published to coincide with the Spaceworks exhibition at the National Maritime Museum

PULLING TOGETHER

By this time members' subscriptions for 1986 should have been paid, so the Society has this income firmly in hand and can budget safely for the cost of its publications and general overheads during the coming year. The need for this is underlined by the fact that every member, on joining, undertakes to abide by the Society's Constitutional Rules, an important one of which is settlement of subscriptions on or before January 1 each year.

The result of not paying subscriptions on time is not only that the Society starts its year with a reduced income but becomes involved in extra expense and staff time due to the despatch of reminder notices so that, essentially, some part of the income from the majority of members who do pay is used to finance the minority who pay late.

We are sympathetic whenever a member faces exceptional personal circumstances or, indeed, is away for a period which delays settlement but, this apart, the Society has to maintain the efficiency of its working operations.

When it comes to subscription renewals, it does this in two ways:

1. By issuing annual subscription notices in good time (mid-October) and asking members to give them prompt attention.

2. By operating a direct debit system whereby members with UK bank accounts can have the matter dealt with automatically, yet allow them full control over any payments made.

The direct debit system is exceptionally good. It is both simple and convenient. Although too late now to add further names to our 1986 list, forms are available for use from January 1 1987. They can be requested simply by ticking the appropriate space on the subscription notice.

Prompt remittance is even more essential now because, under Article 13 of the Society's newly-adopted Constitutional Rules, any member who has not remitted by March 31 is deemed to have resigned with late payment not necessarily leading to re-election.

THANKS FOR YOUR HELP

At this time of year, Society staff are extra busy processing members' subscriptions renewals and sending out details of the Society to those whose names were forwarded by members on their subscription forms.

Membership promotion is an important and on-going activity and the assistance which many have provided is invaluable.

At present the follow-up process is still in hand. So far the response has been encouraging and could amount finally to several hundred new members. Our thanks to everyone for their help.

CONGRATULATIONS

. . . to Phil Cleator and Len Carter on their election to the International Academy of Astronautics (IAA) as reported elsewhere in this issue.

The introduction by the IAA of a fourth section of

membership, the Social Sciences Section, now enables recognition to be made to those, like Phil Cleator, the Founder of the Society, and Len Carter, its Executive Secretary, who have made considerable contributions to astronautics through their concern with the impact of space science and technology upon society.

SO NEAR AND YET SO FAR

Wet and windy weather greeted the visits organised by the Society to Greenwich Observatory on the nights of December 3 and 4 and put paid to plans for two groups of members to observe Halley's comet with the 28 inch refractor. Tantilisingly, some stars were visible for part of the first evening, giving hope that the weather might clear, but the hope was not realised. Members had to be content to see a photograph of the comet taken a week earlier, still appearing as a small dot without any visible tail. Had they seen the original, each would have received a Certificate to that effect!

Practically all the members who had expressed interest in the visit turned up and were able to inspect the telescope. Those who came early were able to visit the "Spaceworks" exhibits at the National Maritime Museum nearby and the special displays at the Old Royal Greenwich Observatory itself.

A call was made during the evening to the Planetarium in a nearby building where the comet's path was projected against the starry background and its present position pinpointed. The demonstration was followed by a short talk with a series of slides on the origin and history of comets generally.

The 28 inch telescope, the seventh largest refractor in the world, was designed by George Biddell Airy (1801-1892) the then Astronomer Royal. It was built in 1894, using a frame actually intended for a smaller telescope but built with an eye to the future. It has a definition of about 1/5th of an arc second, a focal length of 324 inches and an all up weight of some six tons. For many years it was used to study double stars but, as is customary with most large telescopes nowadays, little visual work is done – photography and image intensifiers play the major role. In fact so much time is spent in reading computer print-outs, that present-day astronomers must have much in common with accountants.

An extra bonus to the visit emerged on inspection of the wall of an outhouse which had been added to Flamsteed's Observatory in 1676 and which turned out to contain the original Halley's tombstone. Apparently it had been cleaned up earlier in the year with the wording picked out in honour of the return of the comet.

Originally, the tombstone had been in the churchyard of St. Margaret's of Lee, London, a mile away, but was taken to the Observatory for safe keeping when Halley's tomb was restored in 1854. Those who go to St. Margarets will still see what appears to be Halley's tombstone though it is really a reproduction!.

The telescope's original dome was stripped of much of its covering by a V1 bomb in 1944 and the instrument was then moved to Herstmonceux. It was returned to Greenwich subsequently and is now snug under a new dome fitted in 1974-5.

Our sincere thanks are due to all the staff at the Old RGO for their hospitality and for providing two most enjoyable and interesting visits. Members have since written to us as follows:

I am writing to say how much I enjoyed the Society's visit to the Old Royal Observatory at Greenwich. I should like to extend my thanks to all who were concerned with organising the trip. Even though conditions were far too cloudy for a glimpse of Halley's comet, which was the main purpose, I nevertheless found the evening to be most enjoyable and instructive. The talk and demonstrations of the planetarium and the large refractor were very enjoyable.

P.W.MILLS, Kent

Using binoculars I first saw Comet Halley in mid-October 1985 when it was a faint 10th magnitude object. I was keen to see the comet in a large telescope and had no hesitation in joining other BIS members in visiting the 28 inch refracting telescope at the Old Royal Observatory at Greenwich on December 3, 1985.

Unfortunately the sky was veiled with thin, high cloud, so the comet was not observed. Nevertheless, it was most interesting to see the telescope and even help to 'operate' it. The planetarium show was interesting, too, and I saw other instruments at the Observatory, many of which were fascinating, particularly some of the chronometers. For me, the visit was worthwhile despite the long journey from the 'Newcastle upon Tyne' area. May I congratulate all those who made the visit possible.

DAVID R. KEEDY, Tyne and Wear

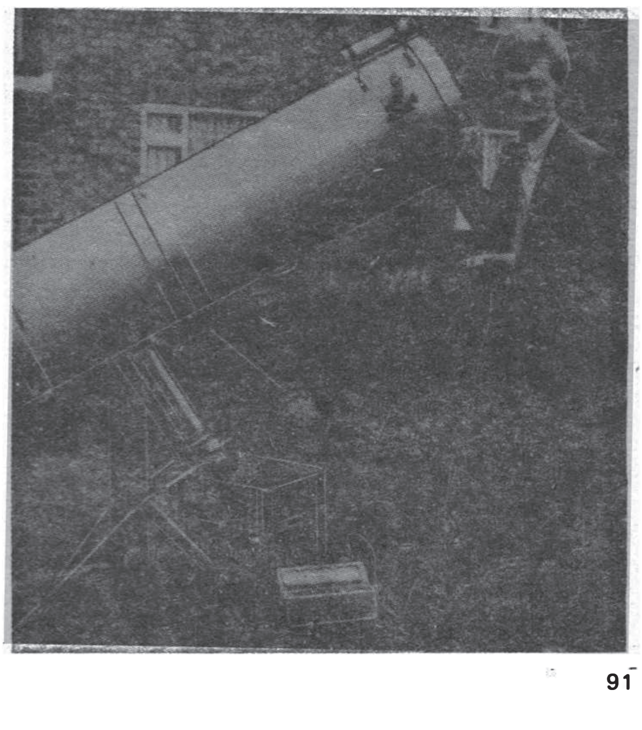
IN ON THE ACTION

Society member Paul Money enjoyed an early sighting of Halley's comet when he saw it at 2.19 BST on September 15 using his 0.35 m reflector from his home in Winceby, Lincolnshire.

The comet was extremely small but was found within 15 minutes of starting the search, its estimated magnitude being about 12.5.

By November 13 Paul and a colleague, Tony Errington, could just make out a small tail using the 0.35 m reflector, with confirmation coming from fellow observers in Liverpool using similar sized instruments.

Paul Money in the back garden of his home in Lincolnshire with his 0.35 m reflecting telescope used to locate Halley's comet as early as mid-September.



LIBRARY ACQUISITION

Flamsteed's *Historiae Coelestis Britannicae* was first issued in 1712 by a committee of the Royal Society headed by Sir Isaac Newton and edited by Edmond Halley in an edition of only 400 copies. Flamsteed not only disowned the publication but bought up 300 copies which, except for the sextant observations, he burnt 'as a sacrifice to Heavenly truth.

The three volumes that made up the later authorised and expanded edition were published posthumously in 1725 and opened a new era in sidereal astronomy.

Shortly afterwards, in 1729, the companion, *Atlas Coelestis,* appeared. This had 27 double-paged engraved star maps on 28 sheets. It was published again in 1753 and yet again in 1781, marking it as the most important star atlas of the 18th century and superior to all earlier atlases. It was said to be 'The Glory of the Whole Work. The Royal Society, however, under the aegis of Newton, had vetoed its earlier publication with the *Historiae,* which explains why it appeared later as a separate work.

Another very important edition of this atlas was published in Paris in 1776 and is usually known as 'The Fortin' edition. It not only elaborated Flamsteed's original 1729 atlas by adding a version of La Caille's Southern Planisphere (which introduced several new constellations), but also included a further constellation plate depicting Corvus and the rear half of Hydra, which Flamsteed had omitted. Amongst other things, the Northern and Southern hemispheres originally drawn by Abraham Sharp were replaced by those of Lemonnier and the text of a star catalogue derived from Bradley's observations added.

This Fortin edition, with 30 star maps on copper was, according to Lelande, edited by Lemonnier. It featured all of Flamsteed's maps but in a reduced size.

The 1776 issue was dedicated to the (French) Royal Academy of Sciences but when a later edition appeared in 1795, augmented with many additional stars, the French Revolution had taken place, thus requiring Dedication to the Third Republic instead.

Our interest stems from the fact that we were recently most fortunate in acquiring a copy of the 1776 Fortin edition of Flamsteed's *Celestial Atlas.* Comparing it with the two copies held at The Royal Astronomical Society shows that their celestial maps are in black and white whereas ours have been most gracefully hand-painted in a variety of rich colours. Whether this was done with a view to detaching and selling the maps individually is unknown but, if it was so, the idea has fortunately been thwarted and a beautiful addition made to the Society's Special Collection instead.

PERSONAL PAPERS

Members may like to know that the Council has approved a plan to maintain a collection of papers relating to leading Fellows of the Society for archival use.

In practice, this is not altogether an easy thing to do for many distinguished Fellows have already passed away and left nothing with us for posterity. To save having to search out suitable materials afterwards — a process both cumbersome and unlikely to lead to satisfactory results — the Library Committee has suggested that the new plan be brought to the attention of all Fellows with a suggestion that they write in with details of the material in their possession.

NEXT 'SPACEFLIGHT'

The March issue of *Spaceflight* will be despatched from our printers by FEBRUARY 21 under new scheduling arrangements designed to provide a speedier news service to our readers. Subsequent issues will also be despatched around the end of the third week of each month. Hitherto, issues have been despatched towards the end of the second week of the month. The later despatch date will enable *Spaceflight* to include more up-to-date news and information. Unavoidably, readers will be receiving the March issue one week later than expected.

NEW CONSTITUTION

From time to time the Society, as it grows, needs to update its Constitution to take account of its needs, experiences, changes in Law and practice and anticipated future developments. One change apparent this time round is the provision that, from 1 January 1986, new Members will be elected to a non-Corporate (i.e. non-voting) grade. The Council has already pointed out that this division into Corporate and Non-Corporate grades is necessary if we are to prepare for the grant of a Royal Charter, which requires Fellows of a Learned Society to be suitably qualified though Members need not possess such qualifications. It is a requirement that shows itself in the exercise of voting rights for the conduct of the Society, the aim being to ensure that control is vested solely in qualified persons.

The change, in reality, applies only to Annual General Meetings and, even then, no loss of rights is involved for those who are already members for, over the 10-year period involved, every existing member will become eligible for transfer to Fellow in recognition of his long membership of the Society while those with technical qualifications may transfer even earlier.

Only five members wrote to comment on the new Constitution, two pointing out that the references to sections of the Companies Act needed updating as a new Act had been passed in the meantime which codified the existing legislation.

Of the others, one was concerned with altering the constitution to make it sexless, substituting 'they' for 'he' irrespective of the provisions of the Interpretation Act which governs such matters. Another saw sinister implications in the whole thing, believing that everything had been engineered to the detriment of everyone by an unspecified intangible group with unclear motives, the argument becoming such a tangle in the end that it proved impossible to venture further. Actually, on both counts the Society, the Council, the staff and all our membership are completely blameless, the points mentioned stemming from requirements of the Law itself, the Privy Council or the Charity Commissioners.

Several 'improvements,' were suggested, one of which, if taken literally, had the effect of ensuring that only one Certificate of Membership would suffice for the whole of our membership, past, present and future. Another, somewhat obscurely, compared the voting rights of members with those of shareholders who had invested money in a business and were thus intent on seeing not only that this was preserved but also that it yielded a profitable income, apparently oblivious of the fact that our Society - a charitable, non-profit making organisation - is concerned solely with the spread of learning and totally dissimilar in practically every respect!

FROM THE SECRETARY'S DESK

David Lasser

The Stockholm Congress provided a wonderful opportunity to talk to David Lasser, now a young man of 83. David produced *The Conquest of Space* in 1931 (2,000 copies were published in the US with a UK edition appearing the same year), the first book I ever read on astronautics and that at a very tender age indeed. I discovered a copy in the local public library but Arthur Clarke, who read a copy about the same time, saw his in a bookshop.

David was the undoubted founder of what is now the American Institute of Aeronautics and Astronautics, then called as the American Interplanetary Society. It all began when, by chance, he saw, an advertisement from Gernsback Brothers for the post of Editor of *Science Wonder Stories*. It was the time of the great depression: the magazine sold for only 25 cents with sales still dropping. He had no editorial experience but an MIT degree which, he says, clinched the job.

The propulsion content of stories then was usually 'a strange and unknown chemical' or substances which 'repelled gravity. Accordingly, David, who had been introduced to the rocket *via* German and Russian experiments, gathered together a group of SF authors to explain that he was dissatisfied with the unscientific methods proposed for flying into space, thus setting up the group that originally formed the AIS to spread the word.

David, though interested in space travel, nonetheless supported the subsequent change of name from the AIS to the American Rocket Society as he believed that there were many willing to experiment with rockets without believing, necessarily, in space travel. The change also led to corporate support.

In 1942, ten years later, the depression was ending. That year saw him talking to President Roosevelt about plans to train people for work again. Roosevelt liked the idea but some of his Committee were so worried that David might be hired as consultant that they introduced a Bill to prevent any money being paid to him!

Their argument was that he was both a radical and a crackpot - having mental dillusions that he could travel to the Moon.

And that in 1942!

Hitch Your Wagon

Ron Draper, Manager of the Mariner Mk II development flight project, kindly took the trouble at Stockholm to update me on CRAF (the comet rendezvous asteroid flyby project), now not likely to start in 1987 but a likely runner for 1988. In the meantime, a switch means that the comet chosen will now be Tempel II with a September 1992 launch. This is not only a very exciting choice but one that should give some very interesting asteroid flyby opportunities on the way.

Among other things, JPL maintains emphemerides of all the known asteroids. With new computer techniques it can pick out ballistic programmes giving a whole range of opportunities for various missions. About 60 staff are working on CRAF at present. Candidate targets must be nearly on the ecliptic and have orbital periods of about 5-7 years.

One excellent flyby would be asteroid 476 (Hedwig), thought to be a dark carbonaceous chrondrite. Besides that, it is believed also to be a binary.

Ron counts himself a very lucky man. He worked on the early Mariners, the Voyager programme and then Galileo. In fact, he has probably been concerned with designing spacecraft to go to every planet in the Solar System except Mercury and Pluto. Ron also performed advance design studies on a US Halley's comet flyby. This was intended to do some close-up imaging though the project never got off the ground as budget problems supervened.

Good Cork

Bruce Adkins, who has set himself the task of finding a comet wine bottle for us, has shown dedication over and above the call of duty. He hasn't yet turned up an actual bottle but he has found a champagne cork containing a comet motif, coming from the Veuve Clicquot Vineyards.

Champagne corks, apparently, often bear the drawing of a comet — this being particularly true of the vineyard in question. Why a comet? Simply because, in the year 1811, a comet passed through the heavens and the harvest was extraordinarily good. It was the same for the champagne vineyards, so 1811 has remained a special year in champagne history ever since.

A Very Long Baseline

A letter with the above heading which appeared in *Spaceflight* recently led me to peruse a copy of Fairbairn's *Crests of the Families of Great Britain.* Idly turning over the pages, I looked at the family crest for the Carters, which turned out to be the head of a lion (My christian name Leonard = Lion) and, if not enough, one depicted with a comet issuing from its mouth!

It was a short stage to a book on epitaphs. I couldn't find one for an astronomer and it is too soon to expect one for a spaceman. Attempts to compose something suitable met with little success. I was, however, rewarded with the story of Bessie-Jane, one of the liveliest mules in World War I. Her grave was marked with a stone reading: 'In her lifetime she kicked two colonels, two majors, two captains, three lieutenants, five sergeants, 11 corporals, 18 privates and one live grenade.'

Around the same time was one reading: 'Here lies Captain Ernest Blomfield, accidently shot by his orderly,' appended by the words 'Well done thou good and faithful servant.'

Readers who would like to compose something suitable for a space worthy, encompassed in two or four lines, might let me know; but never forget the epitaph ending, 'So be prepared to follow me,' to which someone added:

'To follow you I'm not content,
How do I know which way you went?'

Lost Horizons

Lack of funds makes us forego many interesting items which the Society would like to hold.

One recent example was a wide selection of notes by the famous French astronomer, Delambre, many of which formed the basis of his classic work, Historie de l'Astronomie, which appeared in six volumes between 1817 and 1827. Although born into an impoverished family, Delambre worked hard to gain a scholarship and soon showed such great interest in astronomy that, at the suggestion of Lalande, an observatory was built especially for him!

An even more collectable item was Selengraphia by J. Hevelius, published in 1647. This, the first complete Lunar Atlas, was far more accurate than any earlier attempt at the subject. It included a series of 40 plates showing in detail surface changes through all the phases of Moon, a work not bettered for over 100 years.

Many of the features found by Hevelius still carry the names he gave them. Hevelius constructed his own astronomical telescope (he gives a valuable account of its manufacture and use in the first two chapters of the book) and studied the Moon from his specially-built observatory in Danzig, with the help of his wife – also a skilled astronomer.

Hevelius designed and engraved most of the fine plates himself from drawings made during the previous night's observations. But obtaining it is a problem: It costs £4,600.

Even an opportunity to acquire the long sought-after comet wine bottle failed, the specimen on offer being immediately snapped-up by a Glass Museum.

On the other hand our collection of pre-war rocket mail covers has been boosted considerably, as also were the first day covers relating to Apollo 11 with the result that our collection of more than 12,000 covers, though not unique, is now very representative.

Space at JPL – from page 70.

With such a frequent rate of return the orbit of Encke's comet could be examined in detail. Encke concluded that the period of the comet was slowly shortening, and he believed that space was filled with a resisting medium which would slow the motion through friction.

Work continued on studies of the orbit after Encke's death in 1865, and it was found that the retardation ceased from 1865 through 1871! Further studies focused on a second periodic comet (Faye), and no effects ascribable to a resistive medium were found. However, Faye does not approach as close to the Sun as Enke, allowing a localised resisting medium to be considered as an explanation.

Writing about 1880 the American astronomer Simon Newcomb summarised the situation: "...either the cause which is supposed to affect the motion of Encke's comet is not a resisting medium, or, if it is such, it is confined to the neighbourhood of the Sun. Considering the improbability of the Sun having an atmosphere which can extend to such a distance, the former should be deemed the more probable alternative."

Newcombe went on to remark that cometary orbits in general were rather difficult to compute precisely – a situation which persists to the present day and is due to non-gravitational forces, particulary from the expulsion of mass from the nucleus (as early at 1835 Bessel had guessed that such a mechanism might be operative). The difficulties which were attendant upon computing a high-precision orbit for Comet Giacobini-Zinner were described in last month's column with regard to the navigation of the ICE spacecraft. Even more extensive ground and spacecraft-based efforts are being conducted for the navigation of the various members of the Halley fleet.

Thus, cometary orbit determination has come a long way from Aristotle's upper-atmosphere speculations. A second major area of investigation concerns the physics of comets: how the observed structures and processes present in the nucleus, coma and tail can be explained in terms of natural law.

The physics of the production of cometary tails is an area of current interest. Two principal types of tails are recognised: dust tails and ion tails. The former type extend in a direction generally away from the Sun for up to ten million kilometres and are often curved in appearance. The particles in these tails move under the combined forces of solar radiation pressure and gravity. Ion tails are straighter in appearance and can run to 10 or 100 million kilometres in length. Their structure varies over a relatively short period of time and results from a complex interaction between the solar wind and the cometary plasma. It is anticipated that the imminent investigations of Comet Halley by spacecraft will yield greatly increased understanding of cometary plasma processes.

The modern physical concepts of interplanetary electromagnetic fields, plasma, the solar wind, and the force exerted by sunlight allows us to formulate reasonable models of cometary tails, but this was not always so.

The thirteenth century philosopher Thomas Aquinas followed Aristotle in the belief that comets were visible because some fiery principle had fallen into the "exhalation" that comprised the comet, and the whole structure had begun to burn. The tail, in this mode, was an extrusion of the flaming mass of material.

By the late nineteenth century electromagnetic effects were becoming part of the physicist's analytical arsenal, and there was widespread speculation that some sort of electrical repulsion betweeen the Sun and the cometary particles might account for the tail. Though a reasonable speculation, this line of thought proved fruitless.

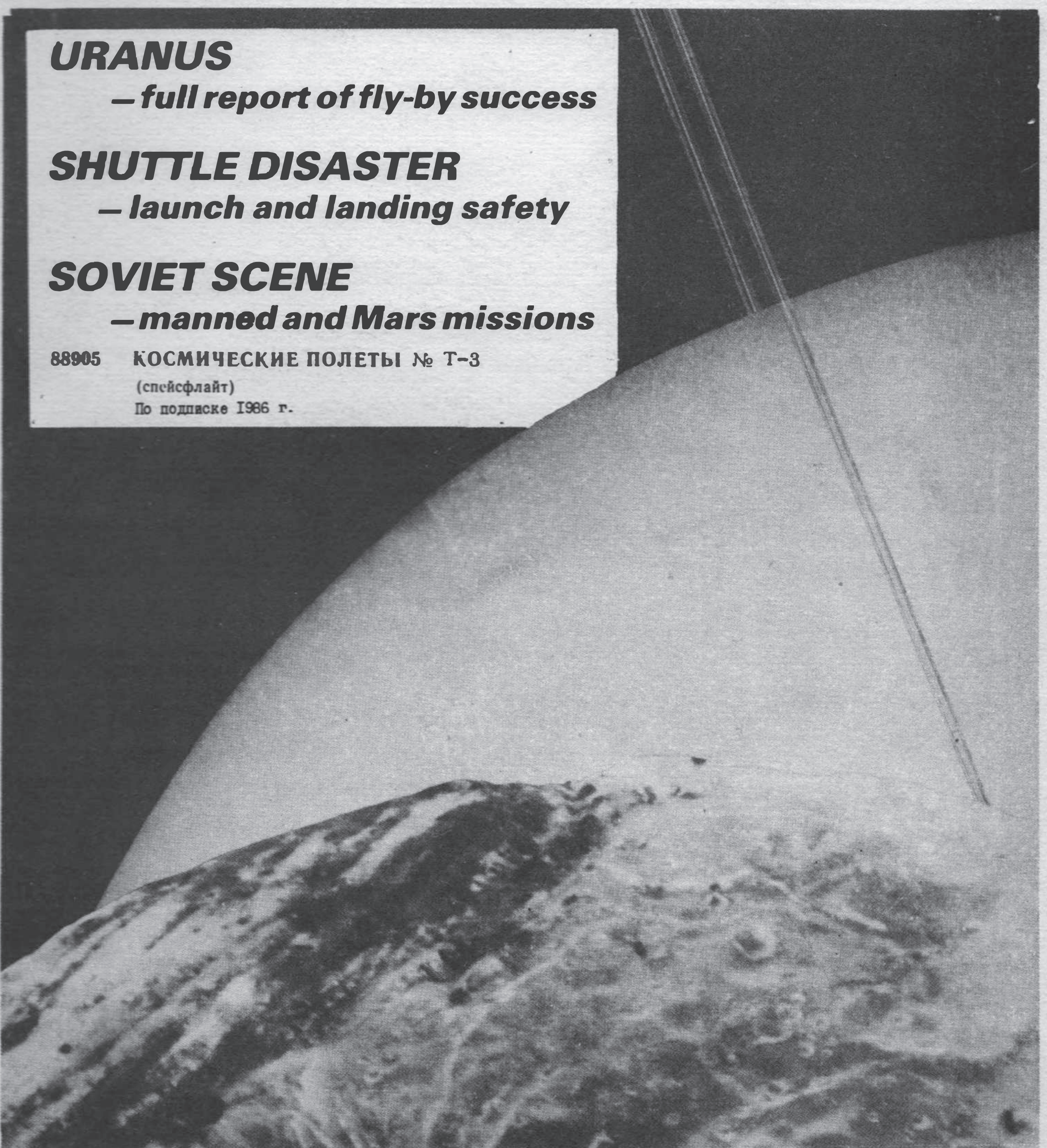
It is fascinating to see how close to the truth, for dust trails, Simon Newcomb came when he lamented that the wave theory of light (due to Huyghens) had triumphed over Newton's corpuscular theory: "The first of these explanations, in the order of time, is due to Kepler, who conceived the matter of the tail to be driven off by the impulsion of the solar rays ... If light were an emission of material particles, as Newton supposed it to be, this view would have some plausibility. But light is now conceived to consist of vibrations in an ethereal medium; and there is no known way in which they could exert any propelling force on matter." (The second explanation of Newcomb was the previously-mentioned theory of electrical repulsion by the Sun.)

The recent surge of cometary exploration promises to extend our knowledge beyond local physics and dynamics even to the origin of the Solar System itself. As noted in last month's column, comets are museums of material condensed from the ancient solar nebula; that's quite an upgrade from being a portent of doom!

MARCH 1986

Spaceflight

The International Magazine of Space and Astronautics



URANUS
— full report of fly-by success

SHUTTLE DISASTER
— launch and landing safety

SOVIET SCENE
— manned and Mars missions

Vol. 28 No.3

SPACE STATION EXPLOITATION

A two day symposium on Wednesday, May 21 and Thursday, May 22, 1986 considering the exciting scientific and commercial openings offered by the Space Station and free-flying platforms.

Programme includes...

UK Involvement in the Space Station
by Roy Gibson, head of the British National Space Centre

Extending the Space Station Infrastructure
by C.M.Hempsell, British Aerospace & Communications Div.

Chemical and Pharmaceutical Applications for the Space Station
by M.J.Leggett

Towards a User-Friendly Space Station
by Dr.E.Mullinger

International Use of Space Station Facilities
by S.R.Dauncey, General Technolgy Systems Ltd.

The Realities of Bioprocessing in Space
by Dr.J.F.Padday

Using the Space Environment
by Dr.F.Kleber

Space Station Control Systems
by S.G.Andrews

JBIS

The March issue of the Journal is devoted to Interstellar Studies and contains the following papers:

Extra-solar Planetary Systems II: Habitable Planets in the Galaxy, by M. J. Fogg.

Antimatter Reactor Dynamics, by R. R. Zito

World Ships and White Dwarfs, by G. L. Matloff.

Sociology of an Interstellar Vehicle, by M. Bloomfield.

The Compatability of the Universe to Complex Order: Paradigms and Speculations, by R. D. Meisner.

Interstellar Travel and Communication Bibliography – 1985 Update.

14th IAA Review Meetings on Communication with Extraterrestrial Intelligence.

This JBIS issue is available at a cost of £2 ($4) per copy, post free, from the British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. England.

CONTENTS

Editor:
G. V. Groves

Assistant Editor:
C. A. Simpson

Managing Editor:
L. J. Carter

Editorial Office:
27/29 South Lambeth Road,
London, SW8 1SZ, England.
Tel: 01-735 3160.

Spaceflight is published 10 times a year and is distributed internationally by post to:

1. Members of the British Interplanetary Society, free of charge.
2. Individual purchasers for personal use at £2.00 (US$4.00) per issue (1986).
3. Libraries at an annual institutional subscription (1986) of £30.00 (US$50.00) inclusive of issues of *Space Education* Magazine.

For Air Mail delivery to non-European countries add £1.50 (US$2.50) per issue. All subscription payments should be sent to the Editorial Office (address above). Details of application for membership of the British Interplanetary Society are available from the Executive Secretary, the British Interplanetary Society at the same address.

* * *

Editorial and advertising enquiries should be addressed to the Editorial office. Responsibility for security and all other clearances necessary for publication rests with the author. Manuscripts are accepted only on condition that all such matters have been completed. Opinions in authored articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

* * *

Published by the British Interplanetary Society Ltd., (No. 402498) Registered Office: 27/29 South Lambeth Road, London SW8 1SZ, England.

Vol. 39 No. 3 — March 1986

Front Cover: A future visitor preparing to land on the icy surface of Uranus' moon Miranda might witness this stunning view towards the planet's cloudtops, some 105,000 km away. This montage of Voyager 2 images obtained in January shows Uranus overlaid with an artist's conception of the planet's dark rings. A portion of the Voyager close-approach image of Miranda in the foreground shows the view along one of the huge canyons that the spacecraft has revealed on the moon's surface. More photographs and a report of this exciting phase of the Voyager 2 mission start on page 120.
JPL

Spaceflight
The International Magazine of Space and Astronautics

COURAGE AND COMMITMENT

The aftermath of the Shuttle launch disaster on January 28 now casts a shadow of uncertainty over a major part of the US Space Program. The technical reasons for the vehicle's structural failure need to be resolved beyond any possible doubt and a Board of Enquiry has this task in hand. A large amount of photographic and material evidence is available for evaluation and the precise sequence of events leading to the failure should not be difficult to identify. Less certain is the time-scale for implementing the remedy as this may involve re-design, manufacture and extensive testing to ensure that no repetition can possibly occur.

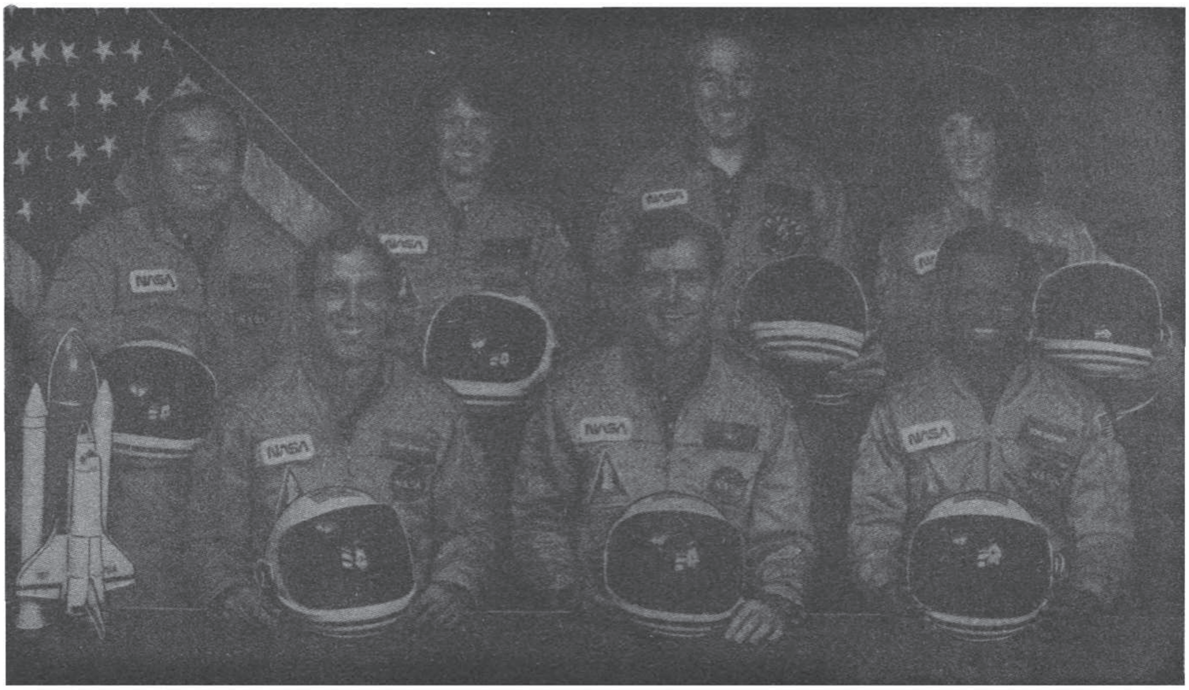
With the Shuttle fleet grounded for a lengthy period, a whole range of Space endeavours scheduled for 1986 will inevitably be hit. The urgent need for of new communications satellites to be placed in orbit can probably be partially met by re-allocating these payloads to unmanned launch vehicles, but for scientific payloads which lack such financial backing the outlook is bleak. In the case of the two interplanetary spacecraft Ulysses and Galileo, only a limited launch window is open for 1986 beyond which their launch must wait until 1987. But the one aspect of the US Space Program for which no alternative exists is the Manned Space Program.

The Shuttle was designed and introduced in the confident belief that man has an essential role to perform in Space – that Space will be just as much a part of his domain as land, sea and air. To date, the activities of astronauts on EVA's and in returning defective spacecraft to Earth have confirmed this belief. The seven or eight crew capacity of the Shuttle has enabled Payload Specialists to monitor the performance of the various Shuttle payloads and also to extend the experience of space flight to the international community.

The first UK astronaut was scheduled to have flown in Space under this arrangement in June. Ironically, the ill-fated Challenger carried the first civilian passenger in a demonstration of the accessibility of Space to the ordinary person. The reversal of fortunes for the Shuttle Program and for NASA could not have been more sudden or more extreme.

As the initial shock of the disaster with the tragic loss of the seven crew members passes, it will be seen that nothing fundamental has happened to change the view that man has an essential role in spaceflight. The plans for a Space Station in the 1990's are just as meaningful now as they were before January 28. The NASA organisation has shown courage and dedication over the years and we are confident that these qualities will enable it to overcome the body-blow that it has been dealt by the loss of the Challenger and crew and will see it through to success again.

Viewpoint



Francis Scobee (46), the spacecraft commander, was on his second flight, the first being in 1984 when he piloted mission 41C.

He became an astronaut in 1978 and prior to that attended the Aerospace Research Pilot School at Edwards Airforce Base, flying such varied aircraft as the Boeing 747, the X-24B, the F-111 and the C-5. In total he had logged more than 6,500 hours of flying in 45 types of aircraft.

He was married and had two children.

Michael Smith (40) was Challenger's pilot. He flew A-6 Intruders and completed a Vietnam cruise while assigned to Attack Squadron aboard the USS Kitty Hawk.

Smith, married with three children, became a NASA astronaut in 1980. He had flown 28 types of civilian and military aircraft, logging over 4,300 flying hours.

Judith Resnik (36) was one of three mission specialists on Challenger. She had a degree and PhD in electrical engineering.

She became an astronaut in 1978 and had previously flown on mission 41D logging 144 hours in space.

Ronald McNair (36) was mission specialist and had also joined the astronaut group in 1978. He had a degree and PhD in physics and while at the Massachusetts Institute of Technology performed some of the earliest developments of chemical and high pressure lasers.

Married with two children, he flew on mission 41B, which saw the first flight of the manned manoeuvring unit, and had logged 191 hours in space.

Ellison Onizuka (39), mission specialist, became a NASA astronaut in 1978.

He was an aerospace flight test engineer for the Sacremento Air Logistics Center.

A mission specialist on Shuttle flight 51C, the first dedicated DoD mission, Onizuka had spent 74 hours in space. He was also married and had two children.

Gregory Jarvis (41), payload specialist, was an electrical engineer and worked designing circuits on the SAM-D missile. Later, as a communications payload engineer he worked on advanced tactical communications satellites before joining Hughes where he was a subsystem engineer on the Marisat programme.

He was married and had no children.

Christa McAuliffe (37), a high school teacher, chosen to be the first private citizen to go into space. She had taught English and American History since 1970 and prior to selection as NASA Teacher in Space also taught economics, law and a course she developed "The American Woman".

McAuliffe, married with two children, was selected as primary candidate for the NASA Teacher in Space project in July 1985.

To the Chief Administrator, NASA

The British Interplanetary Society extends its deep condolences to NASA and the relatives and friends of the gallant crew of the Space Shuttle Challenger who on 28th January 1986 gave their lives in the great endeavour of Space Exploration.

BIS, London

72 Seconds to Disaster

The Challenger launch tragedy has sent a shock wave through the American space programme. In this special 12-page report* Spaceflight *examines the immediate implications and looks in detail at important aspects of the Space Shuttle programme. Written by Clive Simpson, Keith Wilson, Frank Sietzen, Roelof Shuiling and Gordon Harris.

Mission 51L

Challenger rose off the launch pad at 1638 GMT on January 28 and was climbing smoothly when it suddenly exploded in a huge fireball about 90 seconds after lift-off. Debris from the 100 ton spacecraft came down over the Atlantic Ocean about 29 kilometres down range from the Cape Canaveral launch site.

The explosion occurred at a height of 15,000 metres while the Shuttle was travelling at three times the speed of sound. Ground control had given the order to throttle up to full power only seconds before.

Television cameras covering the launch live showed flaming debris trailing with white smoke as it fell into the sea. The solid rocket boosters could also be seen spiralling out of control. They were destroyed by remote control at the order of flight safety officers to prevent any possible impact on populated areas.

No escape capsules or emergency parachutes were carried by the Shuttle and in such an accident it is doubful whether such devices could have been used effectively by the crew.

The deaths of the seven member crew made this the worst disaster in the history of the American space programme and the first ever in-the-air tragedy out of 56 manned missions.

A MESSAGE OF HOPE

President Reagan mourned the loss of seven American astronauts in the explosion of the Space Shuttle on January 28 and praised their courage in remarks to the nation over television and radio.

Nineteen years ago, almost to the day, we lost three astronauts in a terrible accident on the ground. But we've never lost an astronaut in flight; we've never had a tragedy like this. And perhaps we've forgotten the courage it took for the crew of the Shuttle. But they, the Challenger Seven, were aware of the dangers, but overcame them and did their jobs brilliantly. We mourn seven heroes.

We have grown used to wonders in this century. It's hard to dazzle us. But for 25 years the United States space program has been doing just that. We've grown used to the idea of space, and perhaps we forget that we've only just begun. We're still pioneers. They, the members of the Challenger crew, were pioneers.

And I want to say something to the school children of America who were watching the live coverage of the Shuttle's take-off. I know it's hard to understand, but sometimes painful things like this happen. It's all part of the process of exploration and discovery. It's all part of taking a chance and expanding man's horizons. The future doesn't belong to the faint-hearted. It belongs to the brave. The Challenger crew were pulling us into the future, and we'll continue to follow them.

I've always had great faith in and respect for our space program, and what happened today does nothing to diminish it. We don't hide our space program. We don't keep secrets and cover things up. We do it all up front and in public. That's the way freedom is, and we wouldn't change it for a minute.

We'll continue our quest in space. There will be more Shuttle flights and more Shuttle crews and, yes, more volunteers, more civilians, more teachers in space. Nothing ends here. Our hopes and our journeys continue.

I want to add that I wish I could talk to every man and woman who works for NASA, or who worked on this mission, and tell them, "Your dedication and professionalism have moved and impressed us for decades. And we know of your anguish – we share it."

There's a coincidence today. On this day 390 years ago, the great explorer, Sir Francis Drake, died aboard ship off the coast of Panama. In his lifetime, the great frontiers were the oceans and an historian later said, "He lived by the sea, died on it, and was buried in it."

Well, today, we can say of the Challenger crew their dedication was, like Drake's, complete. The crew of the Space Shuttle Challenger honoured us by the manner in which they lived their lives. We will never forget them, nor the last time we saw them, this morning, as they prepared for their journey and waved good-bye, and "slipped the surly bonds of Earth" to "touch the face of God."

Launch of Challenger had been postponed three times due to poor weather at the Cape and on the morning of lift-off had been put back some two hours because of ice on the launch pad caused by freezing overnight temperatures. At one point during the night long icicles were seen hanging from the Shuttle's giant launch pad structure.

The following is a transcript of mission control communication and commentary:

Public Address Officer: One minute away from picking up the count for the final 9 minutes of the countdown in today's launch. The countdown is simply a series of checks that people go through in preparation to insure that everything is ready for flight. The countdown for a launch like the 51L mission is four volumes and more than two thousand pages.

Fifteen seconds away from resuming the countdown and looking at the launch of 51L at 11:38.

And we are at T-9 minutes and counting. The ground launch sequencer program has been initiated.

Voice: APU voice recorder?

Challenger: LPS will do.

Voice: An LPS place all (garble) printer pointers on one.

Challenger: Okay, got it.

Voice: And I still need your verification when you get motion on the opposite corner.

Challenger: Initial copy.

Voice: (garble) this was not performed.

PAO: T minus 8 minutes 30 seconds and counting. All the flight instrument recorders are turned on. Mission Control has turned on the auxiliary data system. This package of flight data from the aerodynamic information coming back as the Orbiter flies through the atmosphere. Coming up on the eight minute point. T minus 8 minutes and counting. Orbiter Test Conductor, Roberta Wryrick, has requested that Houston send the stored program commands which is the final update on antenna management based on lift-off time and sets the system which makes the Orbiter compatible with down range tracking stations.

Challenger: Okay, that's the point.

PAO: T minus 7 minutes, 30 seconds and the ground launch sequencer has started retracking the Orbiter crew access arm. This is the walkway used by the astronauts to climb in the vehicle. And that arm can be put back in place within about 15 to 20 seconds if an emergency should arise. Coming up on the 7 minute point in the countdown. T minus 7 minutes and counting. The next major step will be when pilot Mike Smith is given a go to perform the auxiliary power unit prestart. T minus 6 minutes and 30 seconds and counting.

Voice: (garble) voice recorders?

Challenger: Roger, wilco.

PAO: Coming up on the 6 minute point in our countdown. – can you prestart?

Challenger: (garble) some more.

PAO: T minus 6 minutes and Orbiter Test Conductor has given pilot Mike Smith the go to perform the auxiliary power unit prestart. Mike has reported back that it is in work. He will configure switches in the cockpit to put the auxiliary power units in the ready to start configuration. Mike Smith reporting that prestart is complete.

T minus 5 minutes 30 seconds and counting and Mission Control has transmitted the signal to start the on-board flight recorders. The two recorders will collect measurements of Shuttle system performance during flight to be played back after the mission. Coming up on the 5 minute point. This is a major milestone where we go for auxiliary power unit start. T minus 5 minutes.

Challenger: Lets go for orbiter APU start. PLP022 performed APU start.

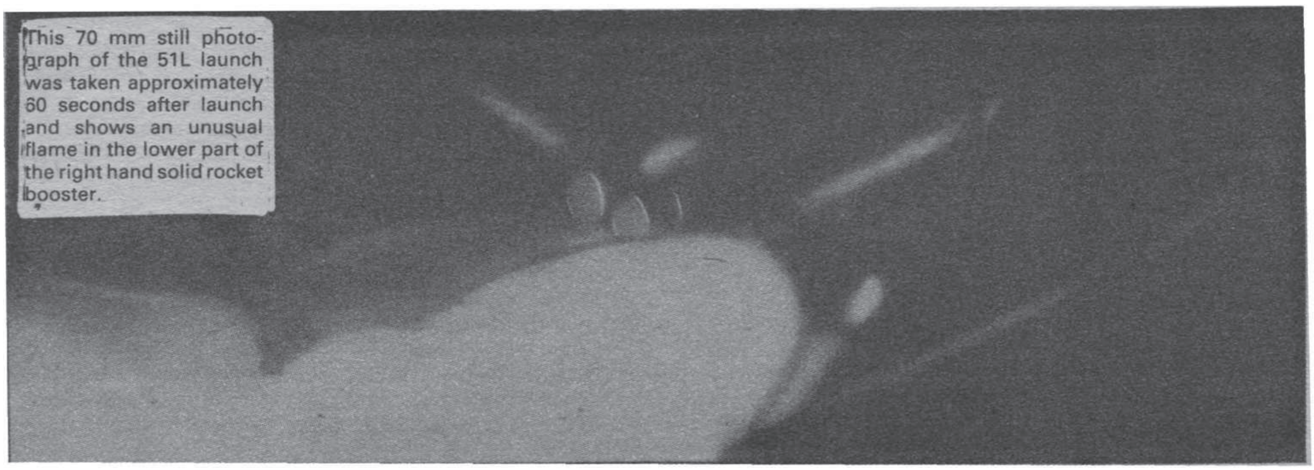
PAO: And we had the pilot ordered to perform the APU restart. Lox replenish has been terminated and liquid oxygen drain back has been initiated. Pilot Mike Smith, now flipping the 3 switches in the cockpit to start each of the 3 auxiliary power units.

T minus 4 minutes 30 seconds and counting. The solid rocket booster and external safe and arm devices have been armed. We have had a report back from Mike Smith that we have three good auxiliary power units. Main fuel valve heaters on the Shuttle main engines have been turned on in preparation for engine start.

T minus 4 minutes and counting. The flight crew has been reminded to close their air tight visors on their launch and entry helmets. And a final purge sequence of the main engines is under way. T minus 3 minutes and 45 seconds and counting. The Orbiter aerosurface test is started. The Orbiter flight control surfaces are now being moved through a preprogrammed pattern to verify that they are ready for launch. T minus 3 minutes and 30 seconds and counting. Orbiter ground support equipment power bus has been turned off and the vehicle is now on internal power. T minus 3 minutes 15 seconds. Aerosurface checks are complete and aerosurfaces in launch configuration. Gimbal checks of the Orbiters main engines are now under way.

T minus 3 minutes and counting. Gimbal checks now complete. External tank liquid oxygen pressurisation has started and purging of the Shuttle's main engines is terminated. T minus 2 minutes and 44 seconds and counting. Retraction has started of the Gaseous Oxygen Vent hood and the ground launch sequencer will make a final check to make sure that that arm is fully retracted at T minus 37 seconds. T minus 2 minutes and 20 seconds. And we have had the pilot, Mike Smith has cleared the caution and memory system. No unexpected error is reported. Liquid oxygen, all its pressure checks are under way. And the liquid oxygen tank approaching flight pressure.

T minus 2 minutes and counting. The liquid hydrogen replenish has been terminated and liquid hydrogen



This 70 mm still photograph of the 51L launch was taken approximately 60 seconds after launch and shows an unusual flame in the lower part of the right hand solid rocket booster.

pressurisation to flight level is under way. The vehicle is now isolated from all ground propellant and fluid loading equipment. T minus one minute and 44 seconds and counting.

Coming up on the 90 seconds point in our countdown. 90 seconds and counting. The 51L mission ready to go. The liquid hydrogen tank now at flight pressure and all three engines ready to go. Coming up on the one minute point in our countdown. Sounds suppression water system now armed. Hydrogen burn ignitors have been armed. These ignitors will be fired at T minus 10 seconds to burn off any residual hydrogen gas. T minus 45 seconds and counting. The solid rocket booster flight instrumentation recorders have gone into the record mode. Coming up on the 30 second point in our countdown. T minus 30 seconds and we have had a go for auto sequence start. The SRB hydraulic power units have started. T minus 21 seconds. And the solid rocket booster engine gimbal now under way. T minus 15 seconds. T minus 10, 9, 8, 7, 6, we have main engine start, 4, 3, 2, 1 and lift off, lift off of the 25th Space Shuttle mission and it has cleared the tower.

Mission Control Center: Watch your roll, Challenger.

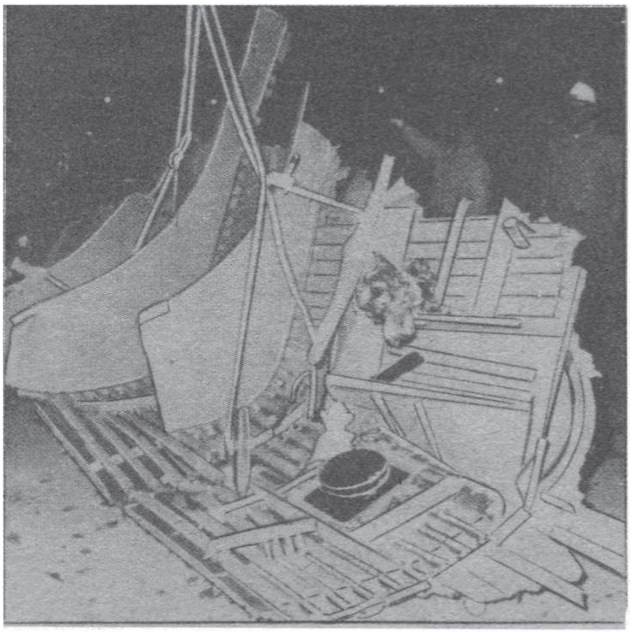
PAO: Roll program confirmed. Challenger now heading down range. Engines beginning throttling down now at 94 percent. Normal throttle for most of the flight is 104 percent. Will throttle down to 65 percent shortly. Engines are at 65 percent. Three engines running normally. Three good fuel cells. Three good APU's. Velocity 22 hundred 57 feet per second. Altitude 4.3 nautical miles, down range distance 3 nautical miles. Engines throttling up, three engines now at 104 percent.

MCC: Challenger, go with throttle up. Roger, go with throttle up.

PAO: One minute, 15 seconds, velocity 29 hundred feet per second, altitude 9 nautical miles, down range distance 7 nautical miles.

Flight controllers here looking very carefully at the situation. Obviously a major malfunction. We have no downlink. We have a report from the flight dynamics's officer that the vehicle has exploded. The flight director confirms that. We are looking at checking with the recovery forces to see what can be done at this point. Contingency procedures are in effect. We will report more as we have information available. Again, a repeat, we have a report relayed through the flight dynamics officer that the vehicle has exploded. We are now looking at all the contingency operations – waiting for word of any recovery forces in the down range field.

Wreckage from Challenger retrieved from the Atlantic Ocean and returned to Cape Canaveral aboard the USCC Cutter Dallas.



FLIGHT RECORD

Gordon L. Harris reports from the Cape

The US space programme came to dead halt following launch of Challenger on its 10th mission January 28 at 11:38 am Eastern Standard Time. The orbiter and its crew of seven vanished in a giant fireball approximately 72 seconds after liftoff. Three Shuttles remain idle at Kennedy Space Center while the agency seeks an explanation for the tragedy.

Adult members of astronaut families and some children stood in horror watching meandering vapour trails in a blue, cloudless sky. Debris rained down into the Atlantic Ocean for more than 30 minutes after the giant flareup.

NASA placed the cost of Challenger at $1.2 billion. With it was consumed a $100 million satellite, part of the worldwide tracking and data relay system, and a smaller device intended to photograph Halley's comet.

Challenger, second of the fleet to roll out of the Rockwell production plant in Palmdale, California, made its debut as STS-6 in April 1983. Later that year the orbiter carried the first US female astronaut, Sally Ride on STS-7 and Guion Bluford, first black astronaut, on STS-8. The ship completed Mission 41D in February 1984, first to land on the KSC runway after a successful mission. Two more flights followed in April and October when Mission 41G carried seven, the largest crew to be launched at the time.

In May, 1985 Challenger carried Spacelab for its first mission and in July it became the first orbiter to "abort to orbit" when No. 1 main engine failed prematurely. In October, 1985 the orbiter carried the first mission for another country, the West German sponsored Spacelab. And its final launch was the first from remodeled Complex 39B, last used for Apollo-Soyuz in 1975.

The mishap could not have occurred at a worse time for NASA. Its administrator is on leave to defend himself against government charges related to his employment at General Dynamics before joining the agency. Jesse Moore, nominal chief of the Shuttle programme, who gave the "go" signal for Challenger's launch, has been chosen to head Johnson Space Center and is now in the midst of the official inquiry. What's more, NASA had begun to justify its new budget request to Congress.

There were strong indications from Washington that despite brave talk of "we won't quit" by Mr. Reagan and others, Congress will insist upon a thorough, time consuming inquiry that may question the continuation of Shuttle flights.

Will NASA try to replace Challenger with a fifth Shuttle? Jesse Moore said the Rockwell plant is still turning out Shuttle spares and could be turned into production but no one was ready to step forward and commit more than $1 billion.

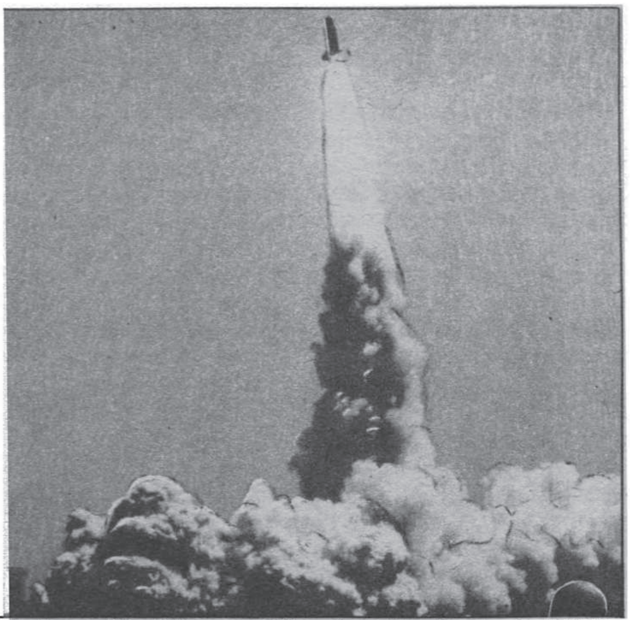
Two satellites built for Shuttle launch are too heavy for Delta vehicles and would require Atlas Centaur. General Dynamics, the builder, has three vehicles that will carry Navy navigation satellites. No one has yet bought such a vehicle for commercial launch. Two more satellites supposed to be launched in 1986 can only be handled within Shuttles.

Air Force Under Secretary Edward Aldridge told Congress in July, 1985 that a four Shuttle fleet would satisfy defence needs. Ten missions per year, he said, will be required for these missions – any other flights essential to the Strategic Defence Initiative would be additional Shuttle missions. When he testified Aldridge said a fifth Shuttle could be justified only by commercial usage. Rockwell international estimated four years would be needed to construct another orbiter.

PLANNING FOR AN EMERGENCY

By Keith T. Wilson

One of the most dangerous phases of a Space Shuttle mission is the launch when a serious malfunction is most likely to occur. Crews are well trained in four available abort options, which can be initiated after booster separation to enable both Orbiter and crew to return safely to Earth. Should an emergency occur before normal booster separation, no abort procedure is immediately available. Unfortunately the explosive nature of the malfunction with mission 51L offered no hope of survival for the crew.



Challenger lifts off from pad 39A on its maiden flight in April 1983.

Introduction

During early Shuttle flights Orbiter Columbia was fitted with ejection seats for emergency use by the two-man crews during the launch phase. However from STS-5, the first operational mission, ejection seats were no longer viable due to the enlarged number of crewmembers.

Four launch abort modes are currently available and selection depends on the altitude that the Shuttle has reached when the emergency occurs. They are (from the earliest possible abort to the last): Return to launch site (RTLS), Trans-Atlantic or Trans-Pacific landing (TAL, TPL), Abort once around (AOA) and Abort to orbit (ATO).

Abort 1

Return to launch site is put into operation if there is loss of thrust on a main engine or some other serious systems failure during the first four minutes of flight which might require an immediate return. Although an abort might be indicated as soon as the Shuttle clears the tower it is not initiated until the Solid Rocket Boosters separate and the Orbiter and External Tank reach an altitude of 107 km at which point a pitcharound manoeuvre is possible. Pitcharound brings the Orbiter from the inverted position it adopts during ascent to an upright one in which it is pointing back towards the launch site. Those main engines remaining operational would assist in the return flight, as would the two Orbital Manoeuvering System engines and a number of thrusters. Following depletion of fuel the Orbiter would pitch down, release the External Tank and glide back to the landing site,

Mission 51F

Challenger Aborts to Orbit

by Roelof L. Shuiling

Challenger's ninth flight (51F), the nineteenth Shuttle mission and the fiftieth US manned spaceflight, came about as close to a launch without actually launching as is possible. On July 12, 1985 the Shuttle aborted its launch three seconds before liftoff after a sensor indicted a malfunction in a coolant valve on main engine number two.

All three main liquid fueled engines had begun operation at that point but the Solid Rocket Boosters had not ignited. Subsequent analysis indicated that the engine did not actually malfunction but the sensor itself did.

The mission finally lifted off on July 29, 1985.

Even after liftoff, however, the Orbiter was not free of problems. At five minutes and 45 seconds into the flight the centre main engine suddenly shut down. Challenger was forced to abort its planned flight parameters and enter an "abort to orbit" mode.

In abort to orbit the Shuttle has enough energy to reach an orbit but not the planned orbit. An abort to orbit leaves open the possibility of completing much of the mission and then landing at a planned landing site.

Gordon Fullerton, Challenger's commander, switched the on-board computers to abort to orbit mode and preplanned abort procedures were begun, which included igniting the Orbital Manoeuvering System engines to burn off 4,400 pounds of fuel. The two remaining main engines fired for about one minute longer than had been planned for the normal flight. Again, a sensor rather than the engine was later determined to be the problem.

Following a burn of the manoeuvring engines, Challenger eventually reached an orbital altitude of 170 nautical miles. The planned altitude had been 206 nautical miles but this lower altitude allowed the flight to be completed with some effect to the sensors on some of the Spacelab 2 experiments.

touchdown occurring between 20 and 30 minutes after lift-off.

Abort 2

The second launch abort option available, a Trans-Atlantic or Trans-Pacific landing, would be used if main engine failure occurred after the four minute mark and before enough energy had been built up to achieve the third abort mode. Once this abort mode had been initiated the Orbiter would turn itself upright, release the External Tank and glide to a contingency landing site. For launches from the Kennedy Space Center a number of Trans-Atlantic abort landing sites exist, selection depending on the inclination to the equator flown by the Shuttle. For 28 degree launches Dakar International airport in Senegal, West Africa would be used, 40 degree launches, as in the case of STS-1, would use Rota in Southern Spain and for 57 degree launches as flown by most Spacelab missions the landing site would be in Northern Spain at Zaragoza. When the Shuttle is launched from Vandenberg Air Force base in 1986 a Trans-Pacific abort landing site will become available at Mataveri airfield on Isla de Pascua, better known as Easter Island, where the runway is at present being modified for emergency Shuttle landings.

Abort 3

The Abort once around phase could also begin at four minutes into the launch provided enough energy was available to allow the Space Shuttle to gain sufficient altitude to reach the US mainland following one orbit. A semi-ballistic trajectory, just short of orbital insertion, would be flown taking the Orbiter around the planet before routine re-entry and landing some 90 minutes after launch. Such an abort would require extra firings of the Orbital Manoeuvering System and attitude control thrusters before and after main engine shutdown to maintain altitude for the circuit.

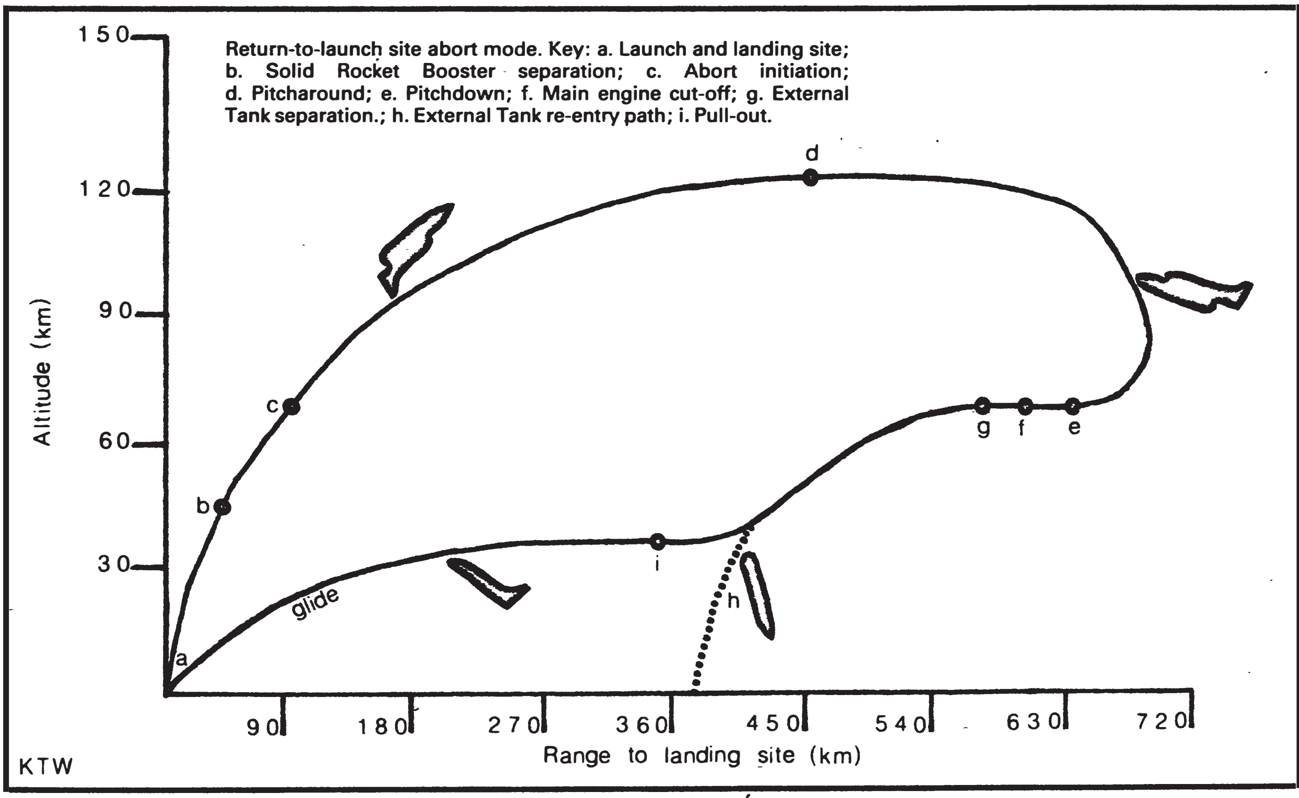
Abort 4

The final launch abort, Abort to orbit, would be used following a main engine failure late in the ascent phase where enough energy existed for the Orbiter to reach a minimal 194 km orbit using remaining engines and Orbital Manoeuvering System engines. This abort mode might also be used if a systems failure occurred during ascent but was not serious enough to require immediate return to Earth. This option allows the Orbiter to reach orbit and remain in space until the future of the mission is decided. This could lead to an immediate landing or to an adapted full-length mission as happened on mission 51F. On that mission one main engine was shut down nearly six minutes into the launch following a faulty engine temperature sensor reading. As all other systems were functioning normally and enough energy existed to reach orbit, ground controllers decided correctly to proceed to orbit. This, the first Shuttle launch abort, resulted in a slightly modified, but successful, mission being flown. The term Abort to orbit tends to be misleading as such an option might not be an abort at all. Following the 51F incident NASA referred to this particular abort as a 'positive two-engine to orbit'.

Launch Emergency

The Challenger accident has focussed attention on the consequences of other kinds of emergency during ascent which might not be immediately catastrophic. If the emergency could be contained until after the Solid Rocket Boosters had burnt out and been jettisoned, one of the above abort procedures may be entered. On the other hand, if the emergency could not be contained, the survivability of the crews becomes conditional on actual circumstances. Resort might be made to separating the Orbiter from the External Tank and SRB's by explosive charges. Circumstances might then permit the Orbiter to ditch in the ocean, where surviving crew members would be recovered by air-sea rescue.

Return-to-launch site abort mode. Key: a. Launch and landing site; b. Solid Rocket Booster separation; c. Abort initiation; d. Pitcharound; e. Pitchdown; f. Main engine cut-off; g. External Tank separation.; h. External Tank re-entry path; i. Pull-out.



KENNEDY SPACE CENTER LANDINGS

By Keith T. Wilson

Before the era of the Space Shuttle all US manned spacecraft returned to Earth by splashing down in the Atlantic or Pacific Oceans. Recovery was a very costly operation. For the Shuttle, the 'space-plane' returns to dry land. And what better than landing at the launch site, the Kennedy Space Center in Florida.

Introduction

The landing speed of a returning Orbiter under normal conditions is 354 km/hr, compared with 209 km/hr for a commercial aircraft such as the DC-9. This high speed necessitates a lengthy runway. The Orbiter also returns unpowered, like a giant glider — the Shuttle pilots have to get it right first time. It was with these two main points in mind that construction of the Shuttle Landing Facility at KSC began in 1974, ten years before the first Orbiter returned from space to the Florida site.

The Landing Facility

The Shuttle Landing Facility, built at a cost of more than $27 million, is located some 3 km to the northwest of the Vehicle Assembly Building and lies on a northwest-southwest alignment. The runway is only part of the facility, which was built in three stages. The runway, towway, parking apron and associated facilities were started in 1974 and work was completed by late 1976. The second construction phase, which centred on the landing aids control building, navigation and instrumentation shelters, communications cabling and mate-demate device foundations, was started in April 1975 and also completed in 1976. The final stage was the installation of navigation, instrumentation and communications systems and ground support equipment; this was completed during 1978.

The Runway

The main feature of the Shuttle Landing Facility is the runway, one of the most impressive in the world. At 4,572 m long and 91.4 m wide, it is twice the length and width of commercial airport runways. It required over 500 hectares of land to build, land that was at one time used for agriculture before being taken over by NASA in the early 1960's. It is not flat but has a camber of 61 cm from the centreline to the edge. A series of grooves each 0.63 cm wide and deep have been cut into the concrete every 2.85 cm across the runway (a total length of 13,600 km of grooves!). Together with the camber they provide rapid drain-off of rain as well as a more skid-resistant surface. A large ditch borders the runway to help cope with water run-off during heavy rains. The 'sandpaper-like roughness' of the grooves, it is thought, could be a factor contributing to excesssive tyre-wear during landings. The concrete used to pave the runway needed 1,000 truckloads of cement and 10,000 of crushed limestone and sand aggregate. 193,000 m^3 of concrete were used in paving the runway and at its centre it is more than 40 cm thick.

Landings can be made from either direction. From the northwest it is designated as Runway 15; from the southeast it is Runway 33. Approach lights point to the centreline, and the threshold and edge lights outline the field as on a commercial runway. Safety overruns of 305 m are provided at each end. One serious hazard common at many commercial airports is the presence of birds. At KSC the hazard came from alligators — they enjoyed wallowing in the drainage ditch, followed by basking on the warm concrete. It was not unusual for KSC employees to have to chase them off before a landing. Recently, however, a low fence has been erected to discourage such intrusions.

Shuttle landings

Orbiters are guided down by the Microwave Scanning Beam Landing System (MSBLS — pronounced 'Miss Bliss') which is accurate to within 99 per cent in bringing an Orbiter to the designated point on the runway. Landing system equipment is duplicated to permit approaches from either direction. The MSBLS azimuth (left-right) measuring equipment

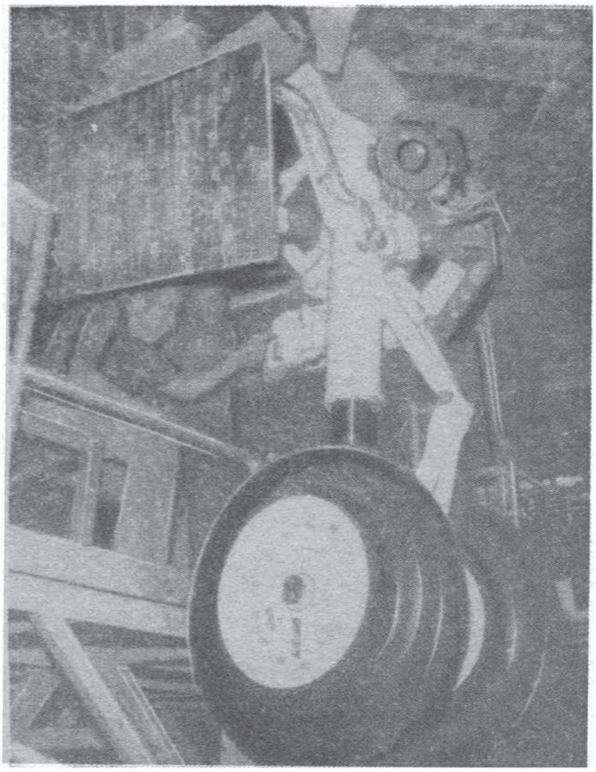
NOSE WHEEL STEERING

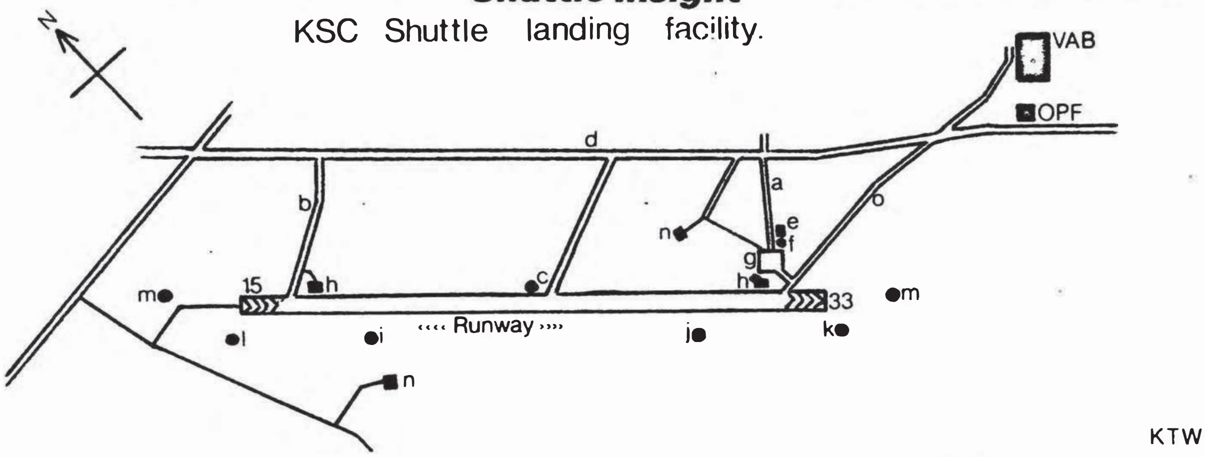
Nose Wheel Steering box and actuator (pictured below) were successfully installed and tested on the Challenger spacecraft during the mission 61A landing at Edwards Airforce Base in early November 1985.

As Challenger touched down and began to slow mission commander Henry Hartsfield put the orbiter through a series of steering manoeuvres to test the steering system.

Success of the test was a key factor in the decision to resume landings at the Kennedy Space Center which were halted following mission 51D when Discovery's brakes locked near the end of its 10,500 foot roll at Kennedy causing a tyre blow out. Prior to the Challenger test all steering during the landing roll had been accomplished by differential braking, particularly demanding in strong cross winds.

Hartsfield, who steered the orbiter 30 feet from the centreline and then back again, reported that the system "performed well"





KSC Shuttle Landing Facility. Key: a. Access Road A; b. Access Road B; c. Crash, Fire, Rescue; d. Kennedy Parkway; e. Landing Aids Control Building; f. Ground Support Equipment Power Panel g. Parking Apron; h. Meteorological Equipment Pad (2); i. MSBLS — Elevation Station Runway 15; j. MSBLS — Elevation Station Runway 33; k. MSBLS — Azimuth/Distance Measuring Equipment Station Runway 15; l. MSBLS — Azimuth/Distance Measuring Equipment Station Runway 33; m. Orbiter Target Aim Point (2); n. Television Tower and Equipment (2); o. Tow-way to Vehicle Assembly Building

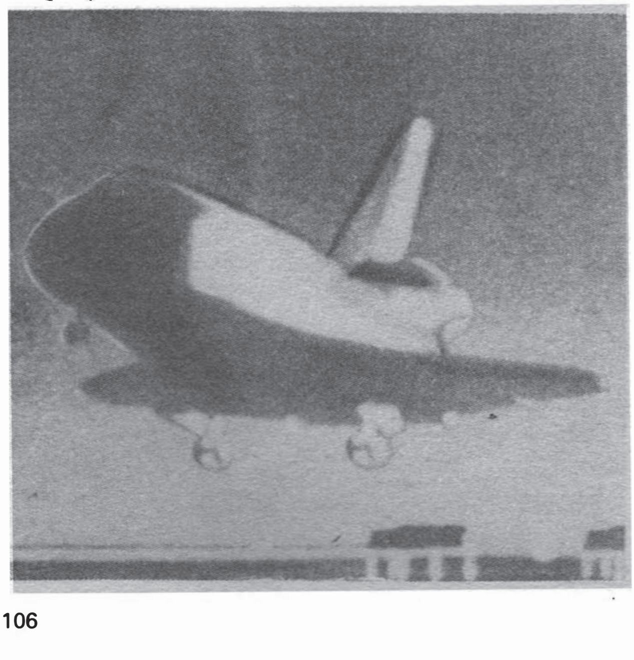
is contained in two shelters, one at each end. They send out signals that sweep 15 degrees on each side of the landing path with directional data. Distance data are also provided. MSBLS elevation stations are located at the side of the runway close to the touchdown point. A vertical beam sweeps the landing path to provide elevation data up to 30 degrees. The MSBLS systems aboard the Orbiter receive these data and the craft adjusts to the correct glide path. In an emergency the Orbiter could be landed safely without intervention by the flight crew. The MSBLS could, in theory, guide the Orbiter's nose-wheel down within the width of the paint stripe on the centre line.

As of October 1985, KSC had seen five landings: missions 41B, 41G, 51A, 51C and 51D. Following braking problems during the cross-wind landing of 51D in April 1985, all future KSC landings were postponed and Edwards Air Force Base in California was used instead. The intention was that KSC landings would be resumed in 1986, depending on the introduction of nose-wheel steering, tested for the first time on mission 61A at Edwards. This elimiates differential braking, which caused the problems on 51D. The 51D crosswind landing at KSC emphasised a problem that had been mentioned in a 1983 report to the US Congress by a committee of the National Research Council. They made the following recommendation: "The crosswind limitations of the Shuttle Orbiter suggest that an additional runway should be considered at KSC to avoid diversions". It is an unlikely prospect because of the high cost involved.

Weather Hampers Mission Scheduling

Shuttle Columbia's night landing at Edwards Airforce Base on January 18 again highlighted the susceptibility of Shuttle missions to poor weather conditions

The first night landing of the Shuttle programme for Challenger at Edwards Airforce Base in September 1983.



Mission 61C astronauts Robert Gibson and Charles Bolden piloted the orbiter to a pre-dawn touchdown – only the second night landing of the programme – after a final opportunity to land at the Kennedy Space Center was reluctantly rejected.

Attempts to land on the Kennedy runway previously, on January 16 (which would have ended the mission a day early to help preserve orbiter processing time) and the following day also had to be called off because of bad weather.

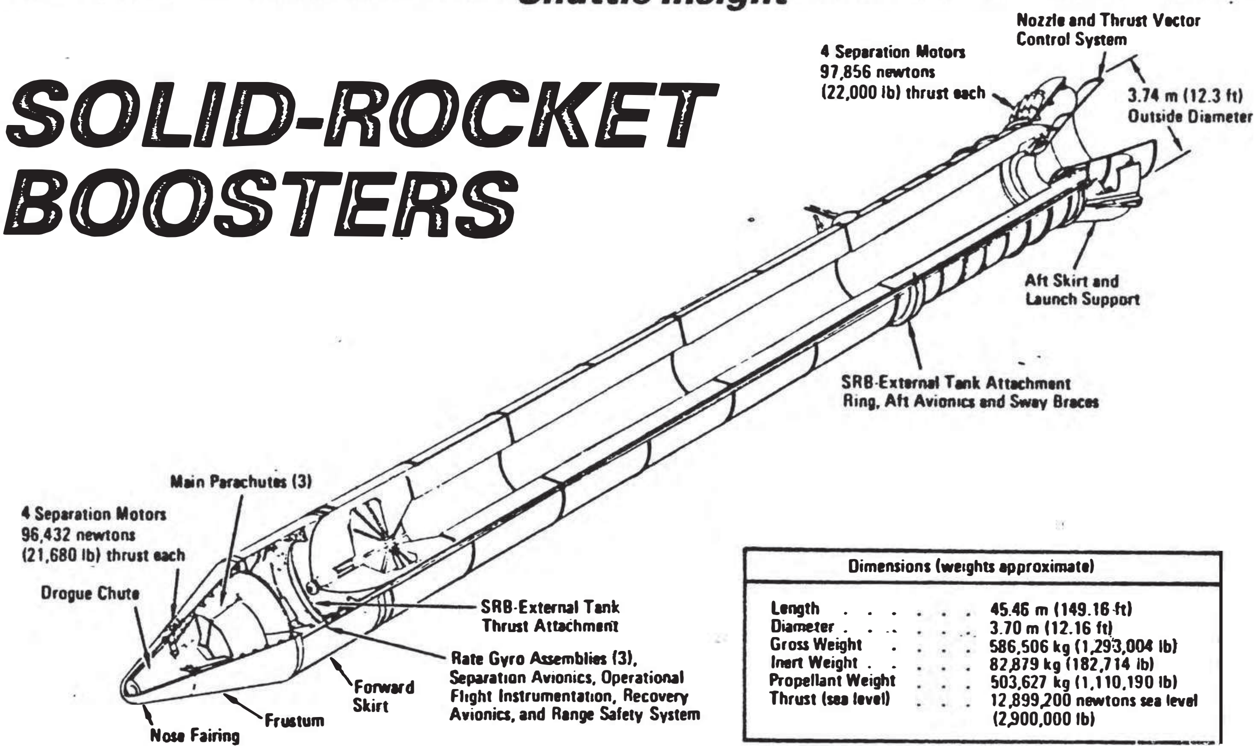
Columbia – the first Shuttle to fly – had not flown for almost two years and during this time had undergone extensive modernisation. Lift-off of mission 61C, which finally occurred on January 12, was the seventh flight for Columbia.

Once again the weather and minor technical problems had delayed this launch seven times – it was originally scheduled for lift-off on December 19 – and the flight was dubbed by the media at large "mission impossible".

Gibson and Bolden piloted Columbia through an ascent profile that placed greater stresses on the vehicle than any previous launch in order to provide additional data on the actual loads encountered during launch compared with projections and earlier flights.

Data from previous Shuttle flights has revealed greater stresses on the vehicle than predicted by wind tunnel and other experiments.

SOLID-ROCKET BOOSTERS



Dimensions (weights approximate)	
Length	45.46 m (149.16 ft)
Diameter	3.70 m (12.16 ft)
Gross Weight	586,506 kg (1,293,004 lb)
Inert Weight	82,879 kg (182,714 lb)
Propellant Weight	503,627 kg (1,110,190 lb)
Thrust (sea level)	12,899,200 newtons sea level (2,900,000 lb)

Close-up pictures of the Challenger 51L launch sequence showed a small flash around the lower third of the external tank and left Solid Rocket Booster (SRB). This appeared to be the trigger for the devastating explosion and NASA investigators are now looking closely at the potential for failure within a joint between segments of the Morton Thiokol/ United Space Booster-built SRB's.

The two SRB's provide the main thrust to lift the Space Shuttle off the pad and up to an altitude of about 45,720 metres (150,000 feet), 24 nautical miles (28 statute miles). In addition, the two SRB's carry the entire weight of the External Tank and Orbiter and transmit the weight load through their structure to the mobile launch platform.

Each booster has a thrust (sea level) of 2.9 million pounds at launch. They are ignited after the three Shuttle main engine thrust level is verified. The two SRB's provide 71.4 per cent of the thrust at lift-off and during first stage ascent.

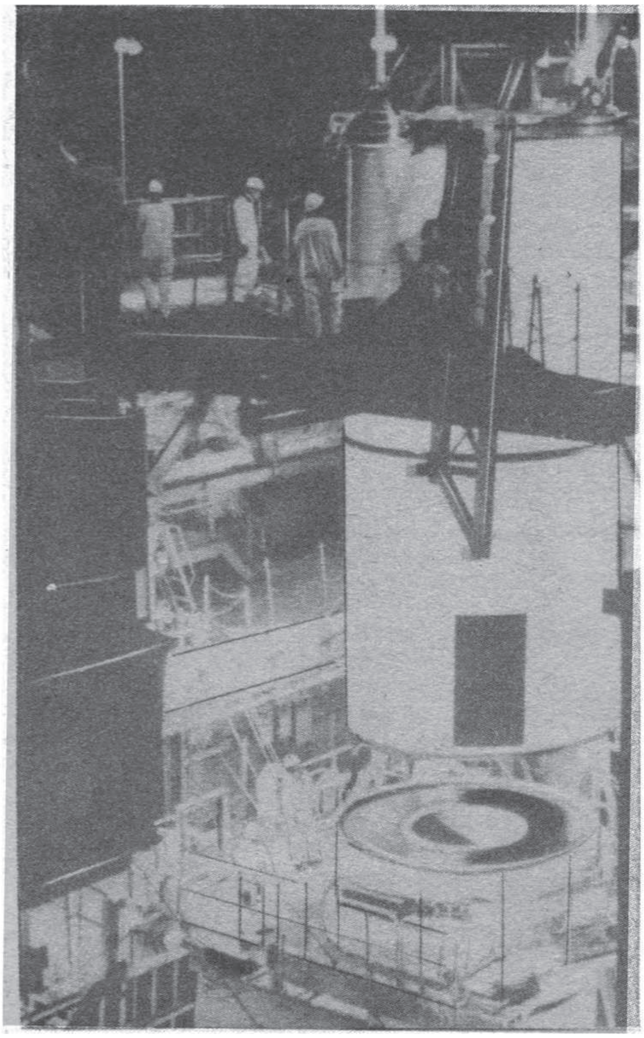
The SRB's are the largest solid-propellant motors ever flown and the first designed for reuse. Each is 45.46 metres long and 3.70 metres in diameter. At launch each weighs 586,506 kilograms, of which 85 per cent, 503,627 kilograms, is propellant.

Primary elements of each booster are the motor (including case, propellant, igniter, and nozzle), structure, separation systems, operational flight instrumentation, recovery avionics, pyrotechnics, deceleration system, thrust vector control system and range safety destruct system.

The interchangeable SRB's are used as matched pairs and each is made up of four solid rocket motor segments. The pairs are matched by loading each of the four motor segments in pairs from the same batches of propellant ingredients to minimise any thrust imbalance. The segmented casing design gives maximum flexibility in fabrication and ease of transportation and handling.

Solid rocket motor ignition commands are sent by the Orbiter computers through the MEC's (Master Event Controllers) to the safe and arm device NSI's

A large crane is used to lower the second booster section onto the aft section in the Vehicle Assembly Building. It is at the junction between the two segments where the leak in Challenger's right SRB is thought to have occurred.



(NASA Standard Initiators) in each SRB.

Three signals must be present simultaneously for the PIC to generate the pyro firing output. These signals – Arm, Fire 1, and Fire 2 – originate in the orbiter computers and are transmitted to the MEC's.

The "arm" signal causes a barrier rotor to move into a position from which redundant NSI's fire through a thin barrier seal down a flame tunnel. This ignites a pyro booster charge, which is retained in the safe arm device behind a perforated plate. The booster charge ignites the propellant in the igniter initiator, and combustion products of this propellant ignite the solid rocket motor initiator, which fires down the length of the solid rocket motor igniting the solid rocket motor propellant.

The computer launch sequence also controls certain critical main propulsion system valves and monitors the engine-ready indications from the main engines. The MPS start commands are issued by the onboard computers at T minus 6.6 seconds (staggered start – engine three, engine two, engine one – all approximately within one-fourth of a second) and the sequence monitors the thrust buildup of each engine.

Normal thrust build-up to the required 90 per cent thrust level will result in the engines being commanded to the liftoff position at T minus 3 seconds as well as the Fire 1 command being issued to arm the SRB's.

At T-0, the two SRB's are ignited, under command of the four onboard computers, separation of the four explosive bolts on each SRB is initiated (each bolt is 711 millimeters – 28 inches – long and 88 millimeters – 3.5 inches – in diameter); the two T-0 umbilicals (one on each side of the spacecraft) are retracted; the onboard master timing unit, event timer, and mission event timers are started; the three main engines are at 100 per cent and the ground launch sequence is terminated.

The solid rocket motor thrust profile is tailored to reduce thrust during the maximum dynamic pressure (max q) region.

The NASA accident review board investigating the cause of the Challenger explosion believes it most likely to have been triggered by a rupture in the right SRB at one of the segment joints.

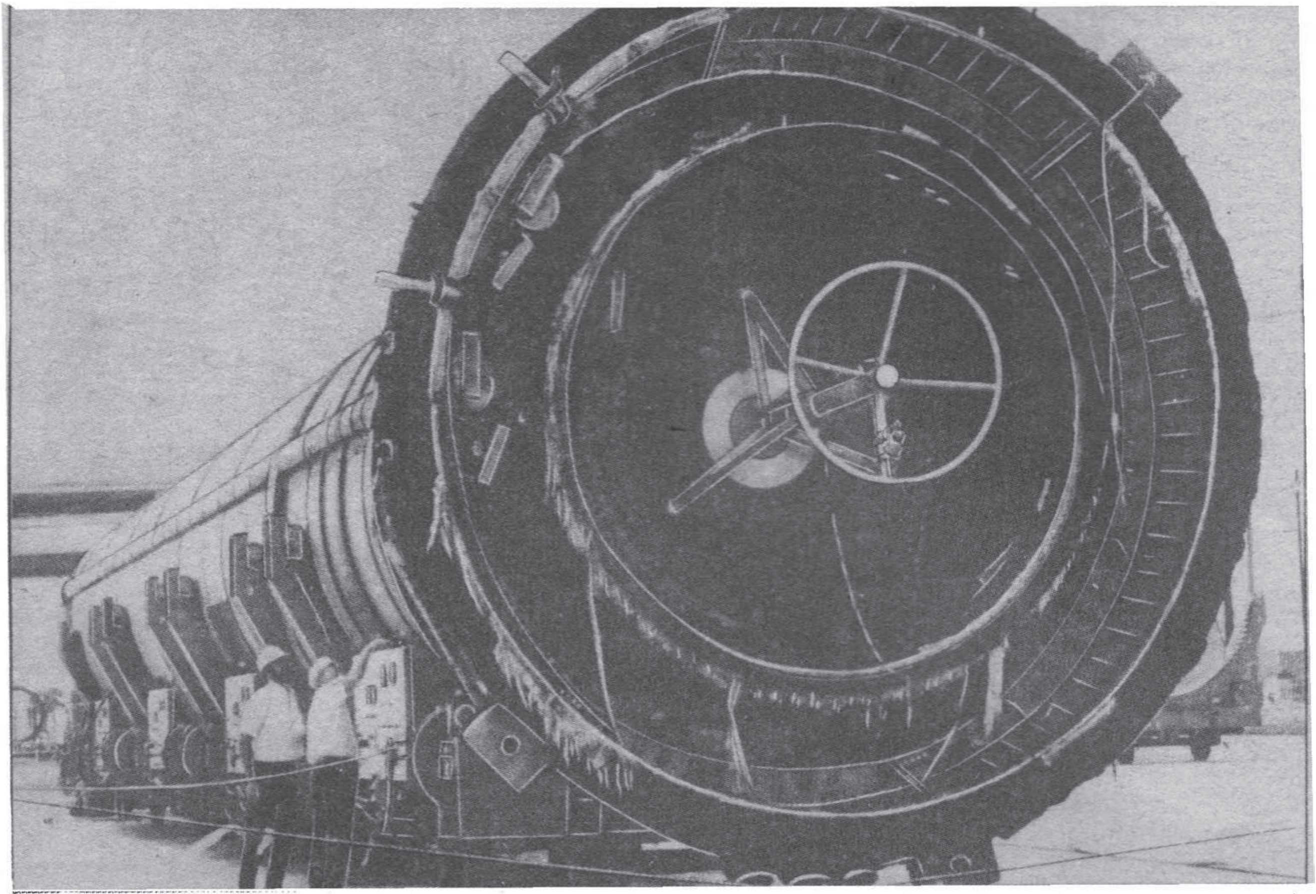
An exhaust plume and flame seen emitting from the side of the booster are thought to have caused the bottom part of the SRB to separate from the external tank, pushing it away from the climbing orbiter.

In response, the top half is believed to have pivoted into the external tank, rupturing the oxygen and hydrogen section which resulted in the massive explosion.

However, finding a reason for the rupture may be less easy. Tests on the structural design of the booster joints together with the seals and lubricants are being performed to establish if the unusually cold pre-launch weather had any adverse effect.

Although the seals are designed to prevent the kind of leak that resulted in the explosion, NASA engineers have recorded on some previous flights slight leakage on the first seal.

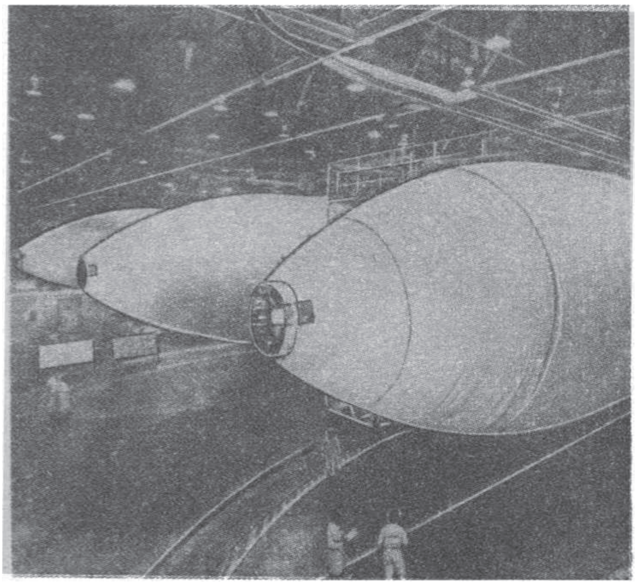
One of the two SRBs used during the launch of Columbia on its third flight in 1982. The booster is at the disassembly facility after being picked up from the ocean about 164 miles north east of the launch site. After being "safed" it is disassembled and shipped out for reprocessing.



EXTERNAL TANK

by Frank Sietzen

The Space Shuttle External Tank is a vital element of the reuseable space transportation system. It not only holds the super-cold liquid propellants for the Orbiter's three main engines but also acts as the backbone of the vehicle in flight. The recent Shuttle explosion in flight has focussed attention on the design and role of the External Tank. The author describes this element of the Shuttle system and how it involves a new technology – that of the very large.



Three External Tanks complete with their layers of insulation - only the first two carried the white finish. *Martin Marietta*

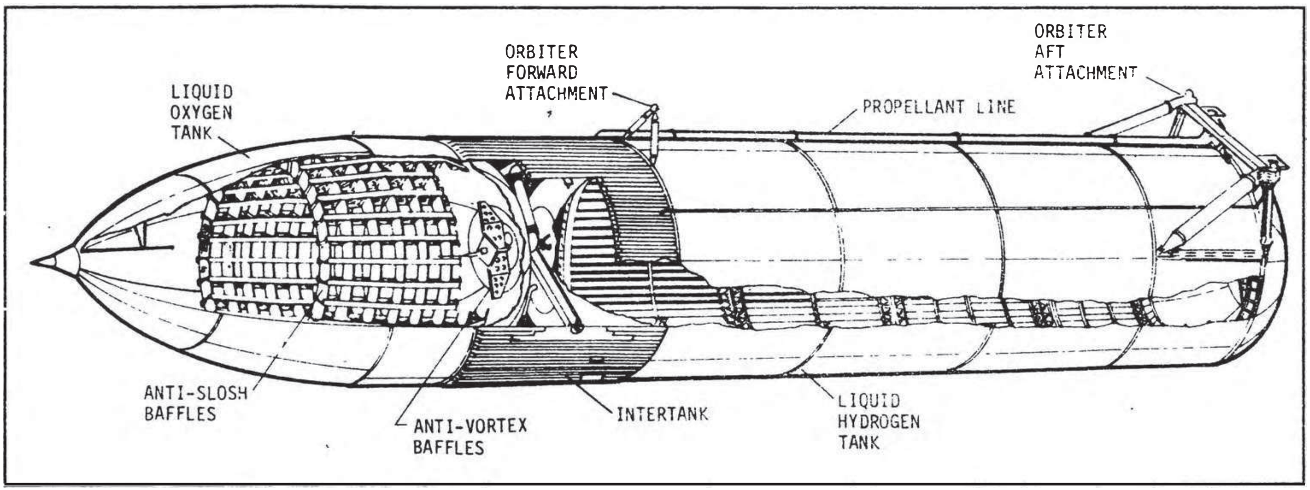
Introduction

The 3500 acre cypress swamp east of New Orleans was made into a permanent plantation home as a result of the labours of Baron Antoine Michoud, the son of a French Cabinet Minister and the third Frenchman to own a tract once infested with alligators and dotted with hunting camps for the Choctaw Indians. Michoud purchased the estate and buildings from a bankrupt civil engineer and sought to make it an appropriate reflection of his lifestyle. Alas, Michoud's personal eccentricities alienated him from the crescent city's business community and he eventually retreated to the confines of the plantation, which he converted to sugar growing and refining. Two smokestacks from those days still stand in front of the assembly plant that bears his name, a silent testimony to the past. Most of Michoud's estate was gradually divided into parcels, with the US government buying a 1,000 acre tract in 1940 to build Liberty ships. Just two years later, when the huge 43 acre plant was finished, it was decided to switch to the manufacture of wooden cargo aircraft. Only two 'planes of an estimated 200 were actually built before that plan, too, was abandoned. Years of inactivity followed.

The coming of the Saturn rocket programme in 1961 finally brought it back to life. It was at Michoud, now a part of the Marshall Space Flight Center, that the Apollo astronauts' journeys to the Moon truly began. The first stages of the Saturn family (Saturn 1, 1B, and the massive 5) were built there from 1961 to 1968, when the assembly lines were stilled and the excess vehicles stored. A Saturn 5 first stage still sits on the lawn at the entrance today, a silent reminder of America's retreat from the Moon of the 1970's. The year after the assembly lines were closed, Congress approved the Space Shuttle programme and in 1973 Martin Marietta was chosen to build the only major expendable Shuttle component, the External (propellant) Tank, at the Michoud site. A prime reason for the decision, as was the case with the Saturn decision a decade before, was the site's access to canals for water transport of the aerospace products that were too large for air travel to their launching sites.

ET Basics

The largest of the several Shuttle elements, the External Tank is 8.4 m in diameter and 47 m long. It is designed to hold more than two million litres of propellants for the Orbiter's three main engines and to be jettisoned from the speeding Shuttle just before orbital insertion. In its pointed, ogive-shaped nose is a liquid oxygen tank that holds 540,000 litres of the oxidizer, with waffle-shaped structures, called baffles, on the inner surface to keep the super-cold liquid from sloshing about during the trek to space. Below that is perhaps the most important part of the overall ET: an intertank connection linking the upper liquid oxygen tank with the liquid hydrogen tank below. Its most important function is to absorb the heavy loads imposed during launch - the ET is the strong backbone of the Space Shuttle.



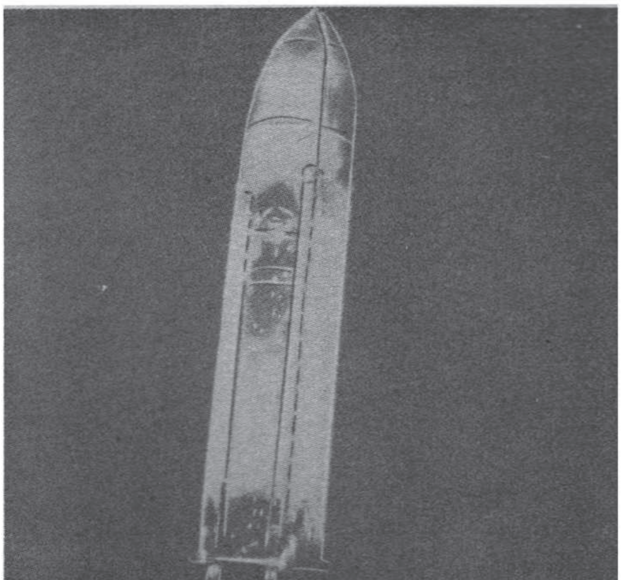
The liquid hydrogen tank, at 29.5 m long, is the largest part of the ET. Like the oxygen portion, it is made of aluminium segments fusion welded together in the 'TIG' or Tungston Inert Gas welding process. The hydrogen fuel, more than 1½ million litres of it, is kept at -253°C, a supercold but high energy fuel.

The exterior of the ET contains propellant feed lines, mounting struts to hold the Orbiter, vents for the use of gaseous hydrogen as an attitude control device during separation, antennae for transmission of destruct commands should things go awry and a Thermal Protection System that covers the entire external surface. Now omitted is the final coat of white paint - at 270 kg and costing $15,000, it was decided that the weight could better be used in the payload bay as cargo. Thus all tanks since the third launch in March 1982 have the natural colour of the thermal insulation. This spray-on protection is an important element: the polyurethane-like foam keeps the liquids at their proper temperature, while preventing ice and frost from forming on the outside. Such material falling off during launch and striking the delicate tiles on the Orbiter is a problem for the reusable ship. Averaging about 2 cm thick, the composition varies at different places. A CPR 488 foam is sprayed over the entire tank, except for the nose and other areas that are subjected to high aerodynamic heating during launch - those are treated with a superlight ablator, sealed with a fire-resistant latex coating that prevents moisture from being absorbed. The insulation is a beige or amber when first sprayed on (the entire tank rotates on a huge turntable while nozzles spray the material in even strokes) but as it is exposed to the ultraviolet rays of the Sun, it cures to a brown-maroon colour. Now that ETs are stored several missions ahead at the Kennedy Space Center in Florida, they will have cured by the time the Shuttle stack rolls out to the pad. For the first use of the lighter, unpainted tank on the third mission the tank cured while on the pad, which aroused the interest of observers who saw a beige tank leave the Vehicle Assembly Building and a brown one on the launch pad!

How the ET Works

The tanks are shipped to Cape Canaveral *via* barge, on a water journey that takes about five days in the Gulf of Mexico. When the Shuttle begins polar ascents from California's Vandenberg Air Force Base in 1986, the water trip for the ET will cross the Panama Canal and take two weeks.

The STS-1 tank separates from *Columbia*, captured by cameras in the umbilical bays underneath the Orbiter. Note the scorching. *NASA*



Once at the launch site, the tank is raised to the launch platform and stacked with the pair of Solid Rocket Motors. Then the Orbiter itself is attached to the ET and the entire stack readied for the trip to the pad (at Vandenberg, the system will be assembled on the pad itself). Once there, electrical and liquid or gas connections are made and the interior tanks purged of contaminants. Several hours before launch, fuel and oxidizer are loaded simultaneously, at various rates of flow as the tanks are filled. With computers watching carefully, the tanks are topped off and any collected gas vapours vented through the nose cap. At 6.6 seconds before lift-off, the propellants are fed to the Orbiter engine cluster at a combined 400 litres/sec through 43 cm wide lines. The ground support umbilical linking the intertank with the launch tower falls away at solid motor ignition and the Shuttle begins an 8½ minute ascent through the atmosphere. At main engine shut-down, pyrotechnic devices separate the ET from the belly of the Orbiter and residual gases in the nose are vented through a valve, beginning a slow pitch-over as a result. This action ensures that it will tumble as it moves below and away from the sub-orbital Shuttle, which then climbs to orbit using the two orbital Maneuvering Engines. The ET plunges back into the atmosphere and breaks up about 55 km above the Indian Ocean. The imparted tumble also helps to assure a small area of impact for surviving fragments. The Orbiter's General Purpose Computers are in control through the short powered flight, reducing the amount of hardware the tank itself requires.

Diets for the ET

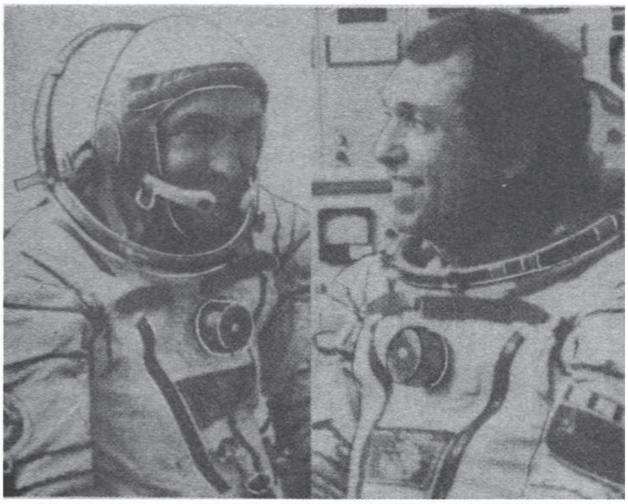
The External Tank is not a static design but is evolving as the Shuttle programme matures. A programme, started in 1979, continues to work at making the ET cheaper and more efficient. The lightweight tank programme set up by NASA called for reducing the weight of the ET by 2720 kg - Martin Marietta was able to deliver a 4500 kg saving, beginning with the tank for *Challenger's* maiden flight in April 1983.

Future ETs may be made more efficient by removing cable trays and baffles and substituting composite material for heavier metals. The challenge is complicated by the slowly increasing demand for ETs: the production rate is presently 14 tanks in various stages of construction at all times. In the not-so-distant future, when a full fleet of Shuttle Orbiters is in service with three launch pads on two coasts, the rate of assembly must gear up to match the rate of growth. Plans currently call for an increase of the current rate to 24 tanks per year by 1988. To support this goal, the Michoud plant itself must be nearly remade from the inside out. This process involves the substitution of new, more efficient manufacturing techniques, such as welding two quarter sections of the liquid hydrogen dome together on a smaller machine and then welding the halves on the original larger machine. The plant is undergoing a facelift of sorts, with an aisle being added that runs the length from east to west, allowing for a more efficient flow of constructed parts, much as in an automobile assembly plant. Martin Marietta representatives in New Orleans refer to this as the '60 minus 36 plan,' meaning that the changes will allow the plant, now gearing up for 24 tanks per year, to grow to support 60 tanks if the rate of Shuttle flights ever require such production levels.

NEW SALYUT SPACE STATION

by Neville Kidger

It is now increasingly likely that the next Soviet cosmonauts to spend a lengthy period in space will do so aboard a new Salyut space station. Meanwhile, further details have also emerged on the sudden return to Earth of the Salyut 7 crew in late November 1985.


Vasyutin (left) and Volkov.

Speculation about the launch of Salyut 8, a replacement space station for Salyut 7, has arisen from revelations of Soviet officials at the IAF conference in Sweden last October. It was reported that the main component of the station would be a central core with multiple docking ports to allow four to six modules to be docked to the station.

A picture, from the US Defence Department publication "Soviet Military Power" shows an enlarged Salyut with two Cosmos Modules docked radially at the rear of the complex. The publication says this is the design of the enlarged Salyut. It has already been noted that the Cosmos modules bear a strong resemblence to the 1960s McDonnel Douglas "Big G" study for a space station but a picture which was published in 1969 (AW&ST 22 September 1969, pp 103) shows "Big G" modules docking laterally with the large cylindrical station. If the DoD drawing is representative of the Salyut 8 design then comparison with the McDonnel Douglas study is unavoidable. The 1969 US study featured an architecture similar to that employed in Skylab (ie with several cylindrical 'rooms' along the length of the station). It will be interesting to see if the Soviets have built their large station interior similar to the US design.

Salyut Mission Report – Working In Orbit

October began for the 'Chegets' – cosmonauts Vasyutin, Savinykh and Volkov – with a series of medical tests. These showed that the men remained in good health, the Soviets said.

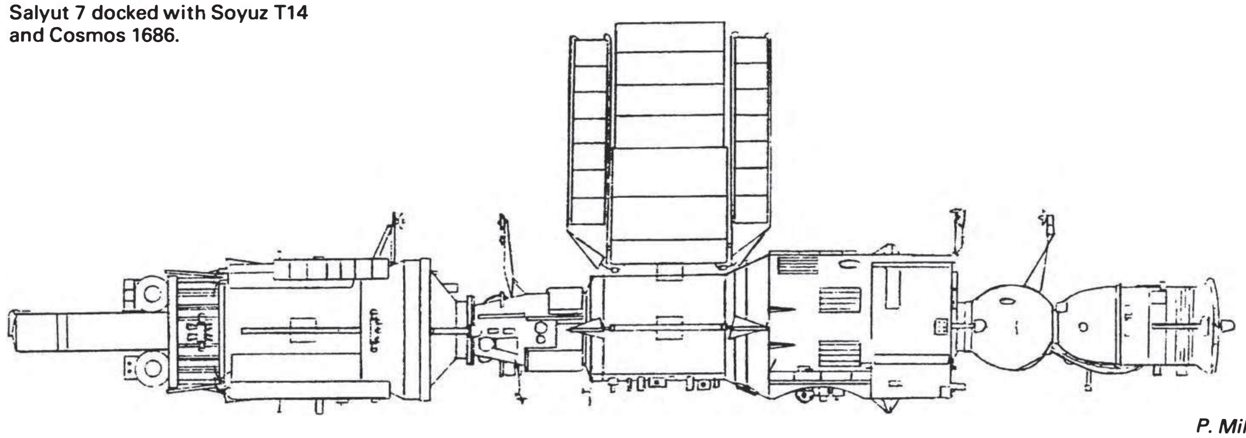
The men were also heavily involved in photography and other data gathering over the USSR. Areas studied included the Black and Caspian seas and areas of the Central Asian Republics.

The cosmonauts monitored the performance of the COMET experiment, a French-Soviet experiment which had been mounted on the exterior of Salyut by Dzhanibekov and Savinykh during their EVA on August 2. The experiment used deployable 'arms' to trap dust particles in the vicinity of the complex and the first collections were timed to coincide with the near passage of Comet Giacobini-Zinner. Studies would allow scientists to determine the chemical composition of the dust particles and by October 10, the Soviets claimed that the first stages of work with the detector had been accomplished.

Another astrophysical experiment conducted extensively by the Chegets involved an improved gamma spectrometer, called 'Mariya', which was placed at various locations in the station to study the mechanism of the generation of currents of high-energy particles such as electrons and positrons in near-Earth space. Work also continued with the 'Pion' technological installation to study the behaviour of materials in weightlessness and the cosmonauts regularly monitored the progress of plants, such as cotton and flax, which they had planted in biological installations.

By October 12 it was reported that the Cosmos module was still not fully unloaded and that the men

Salyut 7 docked with Soyuz T14 and Cosmos 1686.


P. Mills

were having to unload it in their spare time. Two days later the cosmonauts took part in a TV session with US astronauts Slayton and Stafford as part of a goodwill exchange. It also involved Congressman Bill Nelson (who flew on Shuttle mission 61C). Nelson was told that the three cosmonauts would still be in orbit during his flight, which was then scheduled for a December 18 launch.

As October passed the men continued their cycle of work of Earth observations, materials studies and astrophysical observations. Special attention was also paid to the cosmonauts health. In an interesting experiment the cosmonauts were used as guinea pigs to study how an increase in the intensity of physical exercise could be used to decrease the length of time the men had to spend on it (typical time per day spent on physical exercises was between two and two-and-a-half hours).

By October 20 the men had begun another series of dust collections with the COMET experiment and had spent time studying the phenomena of noctilucent clouds at an altitude of 80 km over the Pacific. During the studies, under the codename 'Aerosol' the attitude of the complex was controlled by the Cosmos satellite.

TASS reported on October 25 that the complex was orbiting at a height of 375 x 357 km at an inclination of 51.6 degress and a period of 91.6 minutes.

During the first ten days of November the cosmonauts continued the cycles of work with TASS reports being issued every four to five days summarising the work. Special photographs were taken of areas around Tajikistan which had recenlty been the epicentre of a severe earthquake. On November 13 the cosmonauts completed more Earth studies but later at 19.11 GMT the same day it was reported by observers that the cosmonauts had suddenly begun to scramble radio transmissions to Earth. However, routine reports of normal working on the station continued.

Subsequent analysis of TASS reports revealed that the last report that the crew were "in good health and feeling well" – a fairly standard phrase in TASS announcements – was issued October 25. Four days later, the agency said that the systems of the complex were functioning normally and the cosmonauts were implementing the flight programme.

TASS stated on November 15 that the men were continuing work aboard the complex and were engaged in astrophysical, biological, geophysical and medical activities. The 'Chibis' suit was used in "an examination of the state of their cardiovascular systems both at rest and under hydrostatic pressure." It was the last offical report from the agency before the dramatic events of November 21, although Soviet radio reports on the flight, describing the work programme, continued up to 0900 GMT November 18. Once again, the omission of any reference to the men's health was significant.

Emergency Return to Earth

At 1136 GMT on November 21 TASS made a short announcement which said that, at 1031 GMT that day, the crew of Soyuz T-14 had landed some 180 km southeast of the city of Dzhezkazgan in Kazakhstan. The agency stated that the men had conducted studies of the Earth's surface, atmosphere and also astrophysical, technological and technical experiments as well as biological and medical studies.

Only in the final paragraph did TASS give the reasons for the termination of the flight: "The cosmonauts' long flight . . . was terminated due to Vladimir Vasyutin's sickness and the need for hospital treatment for him."

Subsequently, TASS reported that the commander was "satisfactory" but that he was being flown to Moscow for urgent treatment. Western observers confirmed that the return had occurred after four days of scrambled radio transmissions. No further details were released about Vasyutin's illness immediately although a later report spoke of "some inner inflamation" which led some western analysts to suspect an attack of appendicitis.

Vasyutin's illness had caused the Soviets to gather another, certainly unwanted, "first" in space – the first time that a manned flight had been terminated early due to the sickness of a crew member.

The next day, at the Baikonur cosmodrome, Maj. Gen. Aleksei Leonov introduced Savinykh and Volkov to the press. The two men praised Vasyutin for his conduct during the descent to Earth. The Soviets played up the achievements of the flight saying that the Earth photography had covered some 16 million sq km of the USSR and over 400 sessions of scientific research had been accomplished.

There were no new reports of the conditon of Vasyutin released in the following days and one western source claimed that the illness had been so sudden that the cosmonauts had been unable to "mothball" the complex. There was some expectation that another flight would follow quickly to man the operational complex. But there was also expectation that the Soviets would launch a new, larger Salyut (number 8) which would have modules docked to it.

Revelations About The Illness

In 'Pravda' on December 29 the Soviets published an abridged version of the diary Savinykh had kept during the flight which revealed the 'illness' suffered by Vasyutin. The publication continued the series of startlingly frank Soviet accounts of their problems which had begun with the Soyuz T-8 failure in 1983.

The Soviets acknowledged that the crew should have been in space over the New Year period at least and said that the cosmonauts had begun to observe "a slight uneasiness" in Vasyutin's behaviour at some point. He was not sleeping and suffered loss of appetite. Savinykh said that he put that down to his mood and they attempted to help him by cracking jokes and offering advice but Vayutin "became ill" and although the commander wished to ride the illness out the situation became worse.

Savinykh said, graphically, that Vasyutin became "a bundle of nerves". After consultations with FCC it was decided to return to Earth to treat Vasyutin and the decision to return was taken on November 17. During preparations for the return Savinykh wrote: "it seemed . . . that he was improving. But still we made the right decision."

Savinykh said that the men were able to screw and unscrew "dozens of bolts" in the complex and cover the portholes. The crew left a note for those who would follow them and Savinykh said that he had also left some things behind "so if I come back again (to Salyut 7) I'll have something to climb into".

PHOBOS LANDER MARS PROJECT

by Brian Harvey

A 460 day unmanned mission to Mars and its moon Phobos during 1988/9 is now in the final stages of design. Landers will be deployed on the Phobos surface and scientists in the Soviet Union hope to receive signals from these and spacecraft left in orbit for up to 12 months.

Phobos is the prime target for two probes to be launched by Dle Proton boosters in July 1988. First spotted by Asaph Hall in 1877, Phobos measures an irregular 27 x 21 x 19 km. It has a cratered, shapeless surface and always keeps the same aspect turned towards the mother planet Mars.

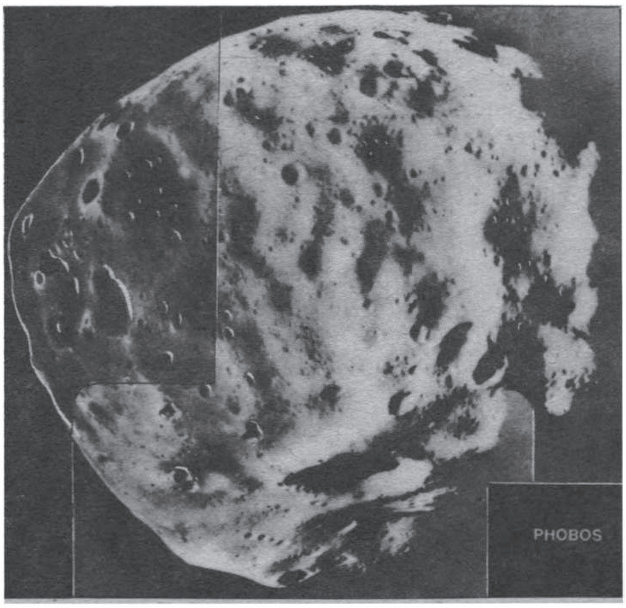
Detailed photographs of the moon were obtained by the American Viking orbiters in 1976-7 confirming earlier predictions that it could possibly be a captured asteroid. Phobos' terrain is dominated by a large 8 km crater, Stickney.

It is not clear from Soviet sources as to whether the second of the two probes to be launched in 1988 will also rendezvous with Phobos, or intercept Mars' other moon Deimos. This smaller moon, measuring 15 x 12 x 11 km is in a much higher orbit of 20,000 km, period 30.3 hrs. In contrast to Phobos, tidal forces are pushing Deimos away from Mars.

Mars-Phobos – mission timetable.

Date	Event
July 15, 1988	Launch of Mars-Phobos 1.*
Feb 2, 1989	Mars orbit insertion. Orbit 4200 by 60,000 km. Period 72 hrs.
Feb 27	Transfer to orbit of 9700 by 60,000 km, period 7070 hrs.
Mar 29	Rendezvous orbit. 9700 km circular. Period 8 hrs. Propulsion unit jettison.
May 3	Encounter phase (125 min) – deployment of landers; close to 50 m at 2 - 5 m/sec; surface remote analysis.
May 3	Post-encounter phase: return to 9700 km circular orbit.
Sep 20	Final Mars orbit of 9400 km by 9700 km. Period 7.6 hrs.
Oct 20	Conclusion of mission.

*This will depend at what exact moment the launching takes advantage of the 10-day window. Subsequent dates will alter accordingly as the launch goes before or after this date



Spacecraft coast to Mars will last 200 days. Mars Orbit Insertion will place the spacecraft in a highly elliptical orbit of 4200 by 60,000 km. A burn of 25 days will raise the periapsis to 9700 km, closer to Phobos' own altitude. A second burn will then lower the apoapsis. A third short burn will place the spacecraft on an interception course to Phobos. At this stage, its work done, the propulsion unit will be dropped.

The main spacecreaft will approach Phobos to a distance of 50 m. During the approach, there are two main events. First, the two surface landers are deployed and second, the main spacecraft will carry out laser and ion analysis of the surface. This phase of the mission will be fully televised.

After interception, the main spacecraft will remain in close proximity to Phobos for 140 days before transferring to a final 7.6 hrs orbit for 30 days.

Each main spacecraft will carry two landers, not one as originally envisaged. The larger of the two will weigh 35 kg and transmit for a year. The landers will carry six experiments, including television, seismic detectors, spectrometers, penetrator, and telephotometer. By the end of the year-long experiment, Soviet scientists hope to have precise measurements of Phobos' orbit and tidal effects. They hope to discover the chemical, thermal, physical and magnetic composition of the rocks. No lander designs have yet been released.

Experiments at interception

Two principal experiments will operate at interception : the remote laser mass spectrometer; and the remote mass analyser of secondary ions. The laser will evaporate and ionise surface material at 50 m range and analyse the free scattered ions in a reflectron. The experiment is being built by scientists from the USSR, Bulgaria, West Germany, the GDR and Czechoslovakia. Afterwards, it should be possible to know in detail the chemical, elemental and isotopic composition of the surface.

The remote mass analyser of secondary ions will identify the degree and manner in which Phobos' surface has absorbed the solar wind. An ion beam will be fired for one second from a distance of 100 m, and

a foil reflectron will analyse the outcome. This is a joint Franco-Soviet experiment.

A number of major experiments are to be directed towards both Phobos and Mars. In one, a radar will be used to scan the surface, structure and relief of Phobos down to a resolution of 35 cm. The same instrument will be used for radio-sounding of the Martian atmosphere. It is hoped to identify the boundaries of the Martian ionosphere and ionopause. and the nature of the Martian magnetic field. This experiment is operated at an altitude of 6300 km and is Soviet-built.

A complete video set will be carried by Mars-Phobos, including three stereo TV cameras and a memory unit able to store 1100 complete frames. The video unit will be used first in Mars orbit, where its resolution will be 7 km, each frame covering 3000 by 2300 km. It will also be used during the encounter with Phobos where its resolution will be 6 cm. It will be used to compile a detailed surface and geological map of the moon.

An infrared spectrometer, made by France and the USSR, will compile thermal maps of Mars and Phobos, identifying the mineral composition of the two bodies. It will be specifically designed to locate heat sources and permafrost.

The gamma spectrometer will study the nature and extent of galactic cosmic rays and related matter on the surface of both Mars and Phobos. It will help identify the chemical composition of the rocks and their radioactivity. This is a Soviet-only experiment.

Mars-only experiments

Two instruments will be carried which will be turned only towards Mars and will not be used in connection with Phobos. These are a neutron moisture meter which will search for water or moisture on the Martian surface and an atmosphere spectrometer. The latter will carry out a detailed analysis of the Mars atmosphere – its ozone, water vapour, oxygen, dust, carbon dioxide – over a sufficient period of time to identify any seasonal changes.

In-flight and solar experiments

Eight inflight instruments will be carried. These include a scanning analyser to study the magnetosphere of Mars and the solar wind; a low energy electron and ion spectrometer; a solar wind spectrometer (similar to that scheduled to fly aboard the ESA spacecraft "Ulysses" in May); a proton/solar wind spectrometer; a low energy solar X-ray spectrometer; two magnetometers; and a plasma-wave analyser.

As Mars-Phobos moves away from the Earth and towards the far side of the Sun, experimental packages will also study the Sun and its radiation. Nine instruments are being carried – an X-ray photometer; a solar ultraviolet radiometer; a gamma-ray spectrometer; a solar cosmic ray detector; and three solar photometers. Mars-Phobos will also carry an X-ray telescope.

The Mars-Phobos missions represent a quantum jump forward in terms of Mars exploration, just as Viking did in the 1970s and Mariner in the 1960s. A total of 31 experiments are planned, a record, and they should lay the firm basis for surface exploration by robots in the 1990s, and the precision required for Mars orbit rendezvous with Phobos will be similar to that ultimately needed on the first manned expedition.

SPECULATIONS ON A MANNED MISSION

The relatively close approach to Earth of Mars in August 2003, when the two planets will be within 56 million km of each other, provides the opportunity for a comparatively short duration manned mission to Mars.

Mohammed Q. Hassan, of the Scientific Research Foundation in Baghdad, evaluates the possibility of a Soviet manned landing during the early part of the 21st Century.

He writes: According to Soviet Scientist Rukavisnikov, speaking in a workshop on "Mars Landing Missions" in 1973, the shortest path to Mars gives a total trip time of 456 days.

Such a mission would allow 210 days for the outward trip, a three week landing period, and the remainder for the return journey. Spaceships for such missions could weigh between 900 and 3000 tons.

Why not then make use of the period between the years 2000 and 2006? Note that in August 2003 the distance between Earth and Mars will be only 56 million km.

Nuclear propulsion could also be considered. For example Soviet expert Prof. Sternfeld stated (1978) that a return trip could be made in less than a year with a stay at the vicinity of Mars of more than a week. This would require a starting velocity of 16 km/s obtained using nuclear propulsion.

It seems likely that the Soviets would send a Manned Mars Exploration Mission using the shortest possible time for such a Mission even if it required much higher delta velocity (DV) in order to reduce the problems of long term weightlessness without artificial gravity.

It will take the Russians no less than five years to reach a one year endurance stay in space, if we base our calculations on extrapolation from the previous long duration missions. (An increment of one month for each new successful endurance mission).

In terms of propulsion one could conclude that there is an active nuclear power propulsion programme going on.

The HLLV could place in orbit a 150-200 ton nuclear powered third stage either of the liquid core or a closed cycle gas reactor type. At least five HLLV launches would be required to assemble the big parts together in Earth's orbit.

One or more Landers could be incorporated and perhaps a small shuttle type spaceplane for skimming in Mars' atmosphere with refuelling capability. Experience with the planned 100 ton space station would provide the basis for the kind of habitable space for a Mars mission.

EUROPEAN RENDEZVOUS

BNSC Cash Boost for Hotol

The British National Space Centre is to provide cash support for proof-of-concept studies on Hotol, the horizontal take-off and landing space plane by British Aerospace and Rolls-Royce.

Studies on Hotol, and its revolutionary propulsion system, Swallow, will last for up to two years and cost £3 million. The contracts placed with the two companies contain a break point after the first six months when the position will be reviewed. The cost of the studies up to that point will be about £750,000 which will be shared equally by the BNSC and industry.

Geoffrey Pattie, Minister of State for Industry and Information Technology, said: "These studies will build on work already funded by the two firms and in particular establish if there are any insuperable difficulties with the concept and to provide credible design, performance and cost data on which to explore the technology with our partners in the European Space Agency.

"Many of the uses we might make of space are ruled out at present by our not having routine and cheap access to space. Even with the vigorous competition between Europe's Ariane launcher and the Space Shuttle, which I hope will soon overcome last week's sad event, getting spacecraft into orbit is still a very expensive business."

The studies on Hotol and Swallow will look at the feasibility of a spaceplane able to carry a load direct to space from a runway, without the need for expensive rocket launch facilities or major preparation lasting many weeks before launches. It would, for example, launch a satellite into an equatorial orbit and return direct to Europe. As it will not need booster rockets it will use less fuel compared with present launchers.

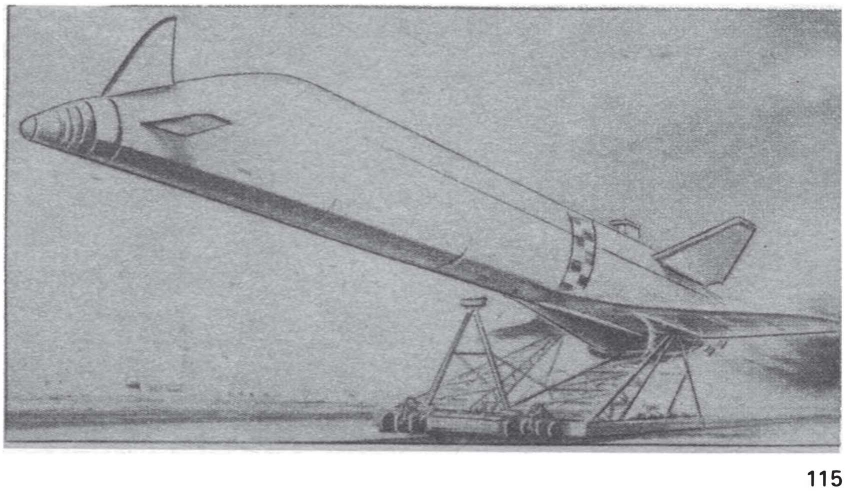
Its goal is to achieve launch costs to low Earth orbit for, say, a seven tonne payload at about one-fifth of those of current launch systems. Hotol's ability to recover satellites and to dock with Europe's Columbus and the American Space Station will also be investigated.

"The studies to be supported are essentially to prove the engine and other technologies involved, prior to considering whether to move into a traditional development programme. If Hotol is confirmed to be a technically and economically viable project, it will need to be considered alongside other long-term European plans, and I will ensure that the opportunity to develop Hotol with European partners remains open," said Mr. Pattie.

Hotol is an advanced concept for a horizontal take-off and landing launch vehicle for satellites based on a new power plant – Swallow – proposed by Rolls Royce. The novel propulsion system reduces the need for Hotol to carry large quantities of liquid fuel by utilising a hybrid engine arrangement which combines air-breathing and rocket propulsion.

In the first instance, Hotol would be developed as an unmanned automatic vehicle but it would be capable of being adapted for manned operations at a later date. Initial studies have already shown that it should have a good cross range capability and be able therefore to return direct to Europe after launching satellites into equatorial orbits. On present forecasts of its weight and volume Hotol will not need thermally insulating tiles like the Space Shuttle for its re-entry into the atmosphere.

In its characteristics and time-scale, Hotol is likely to be complementary to the projects of Ariane 5 already being undertaken by the European Space Agency with a planned in-service date of 1995 and to Hermes, a vehicle designed to be carried into space on Ariane 5 and able to stay in-orbit for periods of up to 30 days. With a crew from two to six astronauts, Hermes has been proposed by the French national space agency, CNES, to follow shortly after Ariane 5.



Hotol would carry a payload of 7-11 tonnes into low Earth orbit. It would use a liquid hydrogen fuel air-breathing engine during the early stages of flight and then draw on liquid oxygen carried on board for the remainder of the flight to low Earth orbit.

The Swallow propulsion system would allow Hotol to take off from a conventional Concorde-length standard runway from a re-useable trolley.

Hotol would climb rapidly clearing commercial airlines after 4-5 minutes and reaching Mach-5 and 26km altitude about 9 minutes after launch.

At this point the engine would cease to air-breath and the vehicle would climb on a higher, rocket-like trajectory.

EUROPEAN RENDEZVOUS

GIOTTO CLOSES IN

Europe's Giotto spacecraft is expected to meet Comet Halley around midnight on March 13 and make a close approach to the dust shrouded and never-before-seen nucleus.

At encounter the spacecraft, with its precious payload of 10 scientific experiments (two from the United Kingdom), will have a closing speed of a fantastic 68 kilometres per second. As it nears its intended 500 kilometre close approach there is a distinct possibility that Giotto will be destroyed or lost through collision with streams of icy dust particles being ejected from the nucleus.

Now visible only in the Southern Hemisphere, recent telescopic observations from both Earth and space show the comet has developed a bright and dust laden head and tail, so coming up to astronomers expectations.

The Comet will return to Northern skies in April and will probably be visible to the naked eye for several weeks before gradually fading as it heads away from the Sun into the cold depths of the Solar System.

Observations of the comet's head show the presence of dense jets of dust which Giotto must avoid if it is to survive long enough in its brief four hour encounter to make worthwhile scientific observations and take the first-ever pictures of the central nucleus.

HEALTHY ORDER BOOK

The number of launch service contracts held by Arianespace now stands at 40 (of which 28 are still to be fulfilled) following the latest contract from Intelsat for the launch of an Intelsat V1 F4 satellite in early 1990.

The satellite, which will be the fifth to be launched by Arianespace for the 110 member country Intelsat, will have the capability to provide more than 30,000 simultaneous telephone calls and three television channels.

Backlog orders secured by Arianespace are now worth more than 7.9 billion French Francs.

SATELLITES IN EDUCATION

An exciting new initiative is being launched that will involve the use of satellites in British schools. Already many enthusiasts, schools and colleges are receiving data directly from radio amateur satellites, University of Surrey satellites and weather satellites.

The use of this data will have a significant impact in the secondary school curriculum. It will:

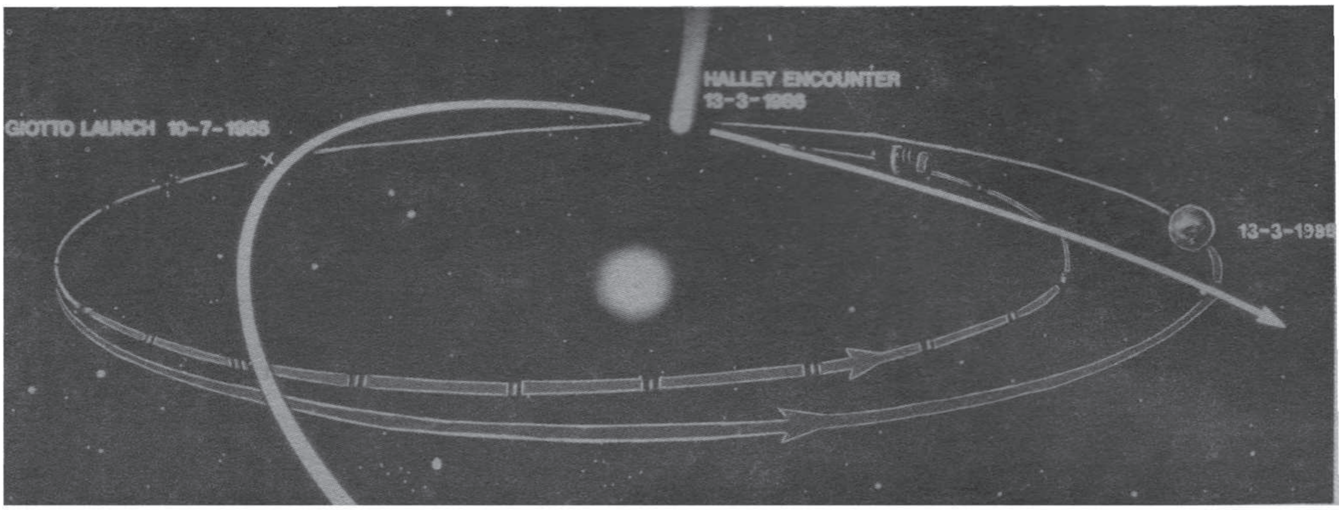
- Provide the opportunity for technological projects such as constructing detecting apparatus and creating computer models.
- Allow experimentation which reflects many aspects of large-scale research, that is collecting, processing and interpreting considerable amounts of live data.
- Promote cross-curricular activities linking mathematics, science and technology with the humanities, particularly geography.

Other education applications currently under way include the use of direct broadcasting satellites as an aid in modern language teaching.

A large number of interested organisations have joined forces to form the UK National Coordinating Committee for Satellites in Education. The group will assist and liaise with teachers who wish to become involved in using satellite data in education; individuals, or institutions who wish to conduct research on the educational use of satellites; and agencies that may fund projects.

Immediate tasks to be tackled by the group include identifying the roles of satellites and satellite data in education; ascertaining what information and equipment teachers need in order to make the best use of the resource and ensuring its development; assessing what software is needed and ensuring its development; and identifying how funds can be used to promote the use of satellites in education.

As part of the initiative a 40-page booklet *Satellites in Education – a guide for teachers* is now available. It is distributed for and on behalf of the National Coordinating Committee by AMSAT (UK), 94 Herongate Road, Wanstead Park, London E12 5EQ, price £3.50 (inc p&p). Cheques should be payable to S.E.U.K.



INTERNATIONAL SPACE REPORT

A monthly review of space news and events

REMOTE SENSING AGREEMENT

NASA and the European Space Agency (ESA), have signed a memorandum of understanding on cooperation in connection with the first ESA Remote Sensing Satellite (ERS-1).

Under the memorandum, ESA has agreed to permit direct readout of ERS-1 Synthetic Aperture Radar (SAR) data, for US government research purposes, at the Fairbanks, Alaska station that NASA is developing in connection with its Navy Remote Ocean Sensing Satellite System Scatterometer (NROSS) programme. In addition to the C-band SAR, ERS-1 will have a C-band scatterometer, a radar altimeter, an infrared radiometer, a microwave sounder and a precise positioning system.

ERS-1 is planned for launch in 1989 and will have a three year projected lifetime, with a possibility for a second flight unit to be launched in 1992/93.

Under the agreement, NASA also will exchange NASA scatterometer and radar imagery for other ERS-1 data of interest. The data received from ERS-1 should enhance NASA and ESA supported polar ice research and complement NASA experimental activities related to NROSS, the ocean Topography Experiment (TOPEX) and Shuttle Imaging Radar-C, all of which are projected to operate in the same time frame as ERS-1.

DELTA LAUNCH DATES

An up-dated launch schedule for the remaining four Delta launch vehicles has been released by NASA. All will lift off from the Eastern Space and Missile Center in Florida and the dates are: Delta 178 (model 3914) carrying the GOES-G satellite, May 1, 1986; Delta 179 (3914) carrying GOES-H, July 17,1986; Delta 180 (3920) DoD payload, August 14,1986; and Delta 181 (3920) DoD payload, August 1987.

SATELLITE MANOEUVRES

Inmarsat has carried out a complex series of satellite manoeuvres to enable it to make maximum use of its in-orbit resources in providing communications services for maritime and other mobile applications.

The process began on January 14 when the Inmarsat Pacific Ocean region traffic was transferred from the Marecs B2 satellite to MCS-D, the Maritime Communications Subsystem aboard the Intelsat V (F8) spacecraft.

This meant that the three coast Earth stations operating in the Inmarsat Pacific region – Ibaraki, Japan; Santa Paula, USA; and Singapore – had to realign their parabolic dish antennas to the new satellite's location at 180 degrees East in geostationary orbit.

Following its activation, engineers at the European Space Agency's satellite operations centre in Darmstadt, Germany, placed the Marecs B2 satellite, which is leased from ESA, in standby mode.

On January 15 ESOC issued a telemetry command through the telemetry, tracking and command station at Ibaraki, Japan, which caused the firing of hydrazine thrusters aboard Marecs B2, nudging it into a five degrees a day drift around the world in a westerly direction. It was due to arrive at its new station, at 26 degrees west over the Atlantic Ocean, on February 25 when it will take over as Inmarsat's Atlantic operational satellite from Marecs A.

Both Marecs satellites are capable of carrying the equivalent of 60 simultaneous telephone calls, but Marecs A has suffered a number of anomolies in its performance.

"Marecs B2 is the newest, and most powerful, of the satellites Inmarsat has in orbit," Inmarsat Director (Technical and Operations) Ahmad Ghais said. "These moves should enable us to use our resources to maximum advantage and to cope with growing demand until the launch of the first Inmarsat-2 satellites in 1988.

"The availability of MCS-D presented Inmarsat with the opportunity to deploy Marecs A in a less sensitive, less heavily loaded, standby role over the Pacific Ocean, and it will be drifted easterly to 177.5 degrees east," he added.

When the manoeuvres are completed Inmarsat system will be configured as follows:

Atlantic	India	Pacific
MARECS B2 26W	INTELSAT MCS-A 63E	INTELSAT MCS-D 180E
INTELSAT MCS-B 18.5W (Spare)	INTELSAT MCS-C 66E (Spare)	MARECS A 177.5E (Spare)

BAHRAIN JOINS INMARSAT

The State of Bahrain has become the 45th member country of Inmarsat – the International Maritime Satellite Organisation.

Inmarsat is the international cooperative organisation that operates a satellite system for the provision of satellite communications services to the world's shipping and offshore industries. It is also planning to offer services for aircraft in the near future (see ***Spaceflight,*** January 1986). Currently more than 4,000 vessels and other units are equipped to operate with the Inmarsat satellites.

Bahrain is the seventh country in the Gulf area to join Inmarsat, others being Iran, Iraq, Kuwait, Oman, Saudi Arabia and the United Arab Emirates.

SATELLITE DIGEST – 190

Robert D. Christy
Continued from the February 1986 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1702, 1985-106A, 16247.

Launched: 1225, 13 November 1985 from Plesetsk by A-2.
Spacecraft date: Possibly based on the Vostok manned spacecraft, with spherical re-entry module, instrument unit and a supplementary package of instruments at the forward end. Length about 6 m, diameter (max) 2.4 m, and mass around 6000 kg.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 356 x 414 km, 92.30 min, 72.88 deg.

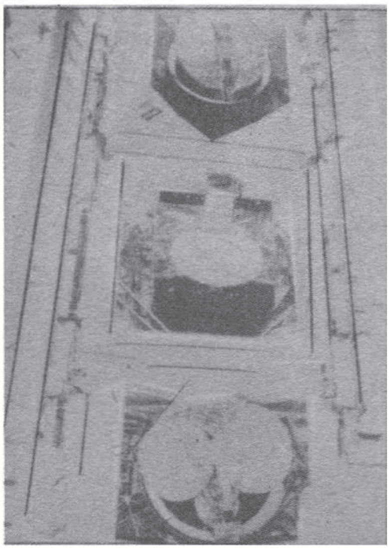
RADUGA 17, 1985-107A,16250

Launched: 1429, 15 November 1985 from Tyuratam by D-1-E.
Spacecraft data: Cylinder with a pair of solar panels, and a multi-dish aerial array at one end. Length 5 m, diameter 2 m, and mass around 2000 kg.
Mission: To provide round the clock radio, television and telegraphic communications within the Soviet Union through the 'Orbita' system.
Orbit: Geosynchronous above 35 deg east longitude.

COSMOS 1703, 1985-108A, 16262

Launched: 2219, 22 November 1985 from Plesetsk by F. vehicle.
Spacecraft data: not available.
Mission: Electronic intelligence gathering.
Orbit: 635 x 666 km, 97.79 min, 82.51 deg.

Cargo for mission 61B is loaded into the payload bay of Atlantis. From bottom to top: Aussat 2, Satcom Ku2 and Morelos B.



STS-61B, 1985-109A, 16273.

Launched: 0029*, 27 November 1985 from the Kennedy Space Center.
Spacecraft data: Shuttle Orbiter 'Atlantis'.
Mission: Carried crew of Shaw, O'Connor, Cleave, Ross, Spring, Walker and Neri (Mexican astronaut). Events included the launchings of three satellites, station keeping experiments with a small visual target vehicle, and testing space construction techniques during two space eva's by Ross and Spring. Atlantis landed at 2123, 3 December at Edwards AFB.
Orbit: Initially 357 x 366 km, 91.59 min, 28.46 deg, then manoeuvered several times.

MORELOS 2, 1985-109B, 16274

Launched: 0747*, 27 November 1985 from the payload bay of 'Atlantis' by PAM-D.
Spacecraft data: Hughes HS-376 type, spin stabilised satellite, cylindrical in shape and covered with solar cells. Diameter 2.16 m, and length 2.84 m, extending to 6.6 m on full deployment of the solar panel. The mass (excluding fuel) is 512 kg.
Mission: Mexican domestic communications satellite placed in orbital storage for up to two years.
Orbit: Geosynchronous above 116 deg west longitude.

AUSSAT 2, 1985-109C, 16275

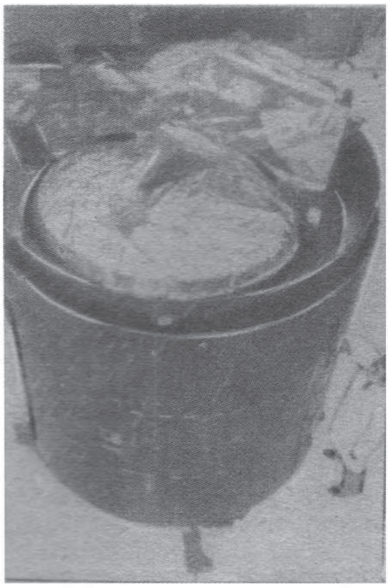
Launched: 0120*, 28 November 1985 from the payload bay of 'Atlantis' by PAM-D.
Spacecraft data: similar to Morelos 3, except that the mass is 655 kg.
Mission: Australian domestic communications satellite.
Orbit: Geosynchronous above 156 deg east longitude.

RCA AMERICOM K2, 1985-109D, 16276.

Launched: 2150, 28 November 1985 from the payload bay of 'Atlantis' by PAM-D2.
Spacecraft data: Three axis stabilised, box shaped body, 1.7 x 2.1 x 1.5 m, with a 15 m span solar array and mass around 1100 kg.
Mission: Commercial communications satellite.
Orbit: Geosynchronous above 81 deg west longitude.

OEX, 1985-109E, 16277.

Launched: 0300, 30 November 1985 from the payload bay of 'Atlantis'.
Spacecraft data: 1 m diameter, circular



Australia's Aussat communications satellite prior to installation in the Shuttle cargo bay for launch during mission 61B.

cross section assembly, put together by the crew from three discs.
Mission: Visual target for station-keeping practice.
Orbit: 368 x 382 km, 91.87 min, 28.48 deg.

COSMOS 1704, 1985-110A, 16291.

Launched: 1312, 28 November 1985 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a drum-shaped solar array with length and diameter both about 2 m. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 965 x 1009 km, 104.91 min, 82.94 deg.

COSMOS 1705, 1095-111A, 16296.

Launched: 1215, 3 December 1985 from Plesetsk by A-2.
Spacecraft data: as Cosmos 1702.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 356 x 415 km, 92.31 min, 72.87 deg.

COSMOS 1706, 1985-112A, 16306.

Launched: 1440, 11 Dec 1985 from Plesetsk by A-2.
Spacecraft data: as Cosmos 1702.
Mission: Military photo-reconnaissance.
Orbit: 162 x 340 km, 89.55 min, 67.16 deg.

INTERNATIONAL SPACE REPORT

COSMOS 1707, 1985-113A, 16326.

Launched: 1552, 12 Dec 1985 from Plesetsk by F Vehicle.
Spacecraft data: not available.
Mission: Electronic intelligence gathering.
Orbit: 634 x 655 km, 97.79 min, 82.54 deg.

USA 13 & USA 14, 1985-114A & 114B, 16328 & 16329.

Launched: 0055, 13 Dec 1985 from Wallops Island by Scout.
Spacecraft description: Uninflated balloon in cylindrical container.
Mission: Two targets for future anti-satellite tests by the USAF. The balloons can be inflated to 2 m diameter.
Orbit: 313 x 774 km, 95.38 min, 37.07 deg.

COSMOS 1708, 1985-115A, 16331

Launched: 0745, 13 Dec 1985 from Plesetsk by A-2.
Spacecraft data: as Cosmos 1703.
Mission: Photo-reconnaissance, all or part of the payload was an Earth resources package, recovered after 14 days.
Orbit: 257 x 273 km, 89.87 min, 82.28 deg.

COSMOS 1709, 1985-116A, 16368.

Launched: 0847, 19 Dec 1985 from Plesetsk by C-1
Spacecraft data: as Cosmos 1704.
Mission: Navigation satellite.
Orbit: 963 x 1013 km, 104.92 min, 82.95 deg.

MOLNIYA-3 (27), 1985-117A, 16393.

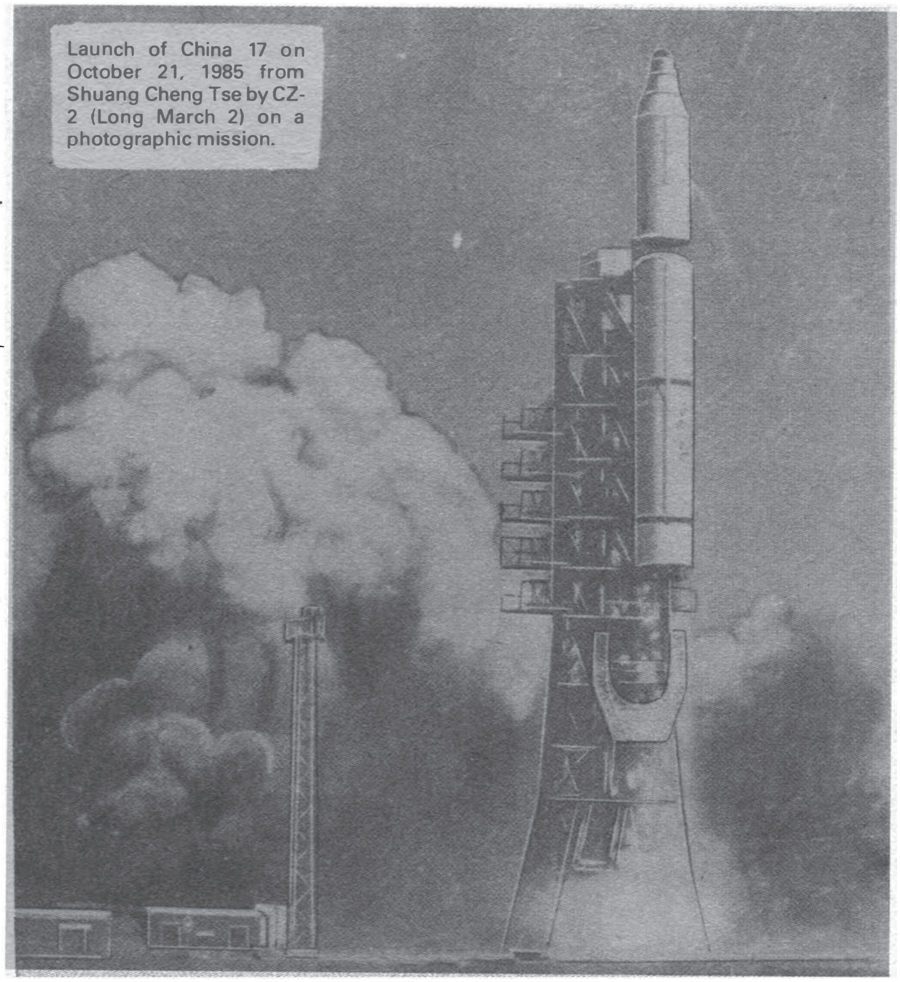
Launched: 1856, 24 Dec 1985 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with conical motor section at one end, deriving power from a 'windmill' of six solar panels. Length 4 m, diameter 1.6 m and mass around 2000 kg.
Orbit: 487 x 39904 km, 718.51 min, 62.85 deg.

COSMOS 1710-1712, 1985-118A-C, 16396-16398.

Launched: 2145, 24 Dec 1985 from Tyuratam, possibly by a version of the D vehicle.
Spacecraft data: not available.
Mission: Navigation satellites in the GLONASS system.
Orbit: 19133 x 19156 km, 676.33 min, 64.84 deg.

METEOR 2 (13), 1985-119A, 16408.

Launched: 0152, 26 Dec 1985 from Plesetsk.
Spacecraft data: Cylindrical body with two, sun-seeking solar panels, length 5 m, diameter 1.5 m and mass around 2000 kg.
Mission: Environmental satellite providing both cloud cover and Earth resources images.
Orbit: 939 x 962km, 104.13 min, 82.54 deg.



Launch of China 17 on October 21, 1985 from Shuang Cheng Tse by CZ-2 (Long March 2) on a photographic mission.

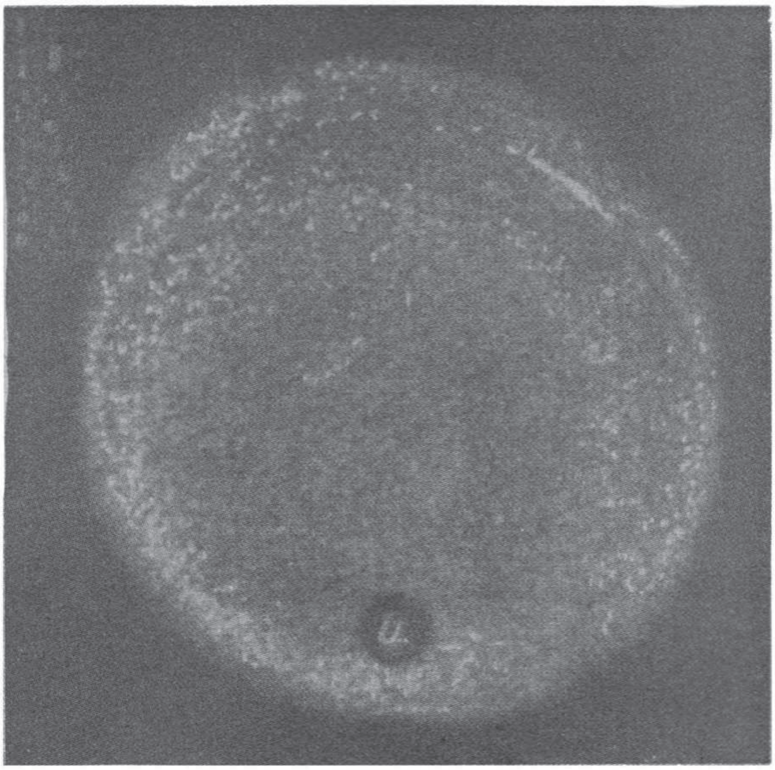
ARIANE LAUNCH MANIFEST

Flight	*Month*	*Launch Vehicle*	
		1986	
V 16	Feb	AR 1	SPOT 1 + VIKING
V 17	Feb	AR 3	G-STAR 2 + BRASILSAT S2
V 18	Mar	AR 2	INTELSAT V-F14
V 19*	May	AR 3	ECS 4 + SPACENET-F3'
V 20	Jul	AR 2 or 3	TV-SAT 1 (or AUSSAT K3 + TC 1C)
V 21	Aug	AR 4	APEX 401
V 22	Sept	AR 3 or 2	AUSSAT K3 + TC 1C (or TV-SAT 1)
V 23	Nov	AR 2	TDF 1
		1987	
V 24	Mar	AR 3	SBS 5 + ECS 5
V 25	Apr	AR 2	INTELSAT V-F13
V 26	May	AR 4	SES + F.O.
V 27	Jun	AR 2 or 3	TELE-X (or OLYMPUS)
V 28	Jul	AR 3 or 2	OLYMPUS (or TELE-X)
V 29	Sep	AR 2 or 4	INTELSAT V-F15 (or DFS 1 + MOP 1)
V 30	Nov	AR 4 or 2	DFS 1 + MOP 1 (or INTELSAT V-F15)
		1988	
V 31	Jan/Feb	AR 4	INTELSAT V1-F3
V 32	Mar/Apr	AR 2	SPOT 2
V 33	May/Jun	AR 4	DFS 2 + HIPPARCOS
V 34	Jul/Aug	AR 4	TDF 2 + F.O.
V 35	Sep/Oct	AR 4	F.O.
V 36	Oct/Nov	AR 4	MOP.2 + F.O.
V 37	Nov/Dec	AR 4	INMARSAT 2-F2 + SKYNET 4C

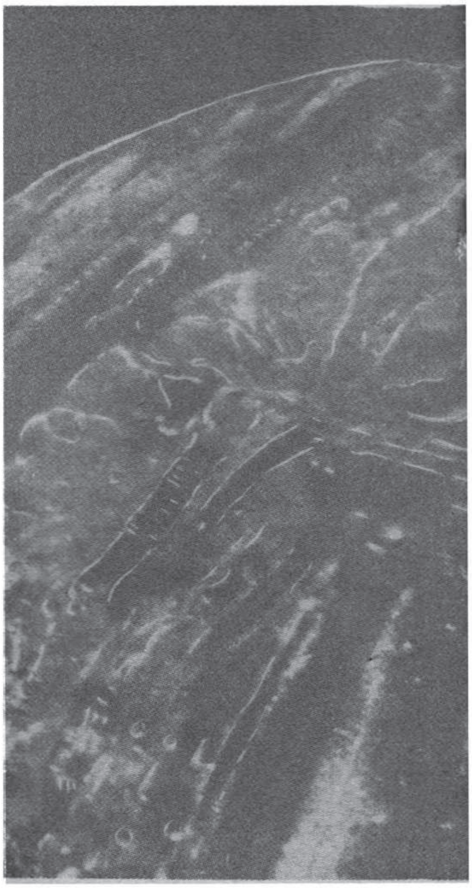
*Priority for AUSSAT K3 in case of unavailability of ECS 4 or SPACENET F3'

F O = Flight Opportunity

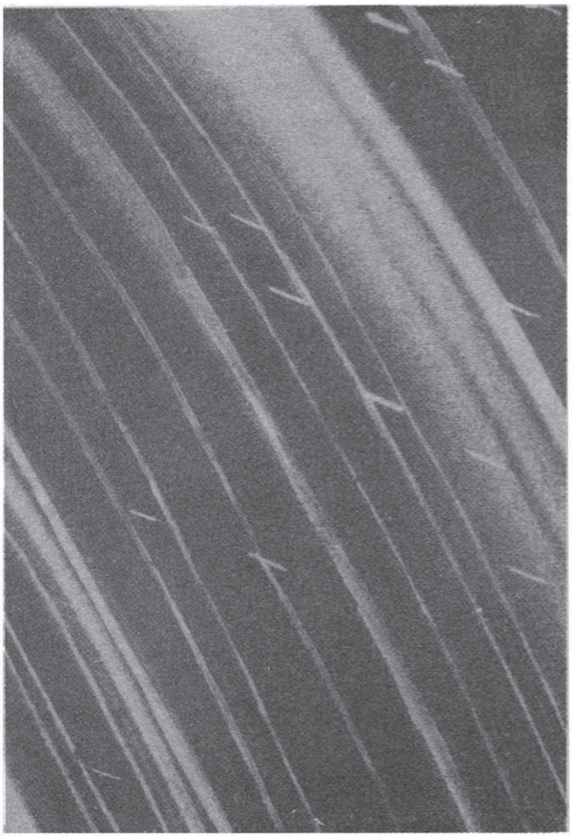
A VOYAGE OF D



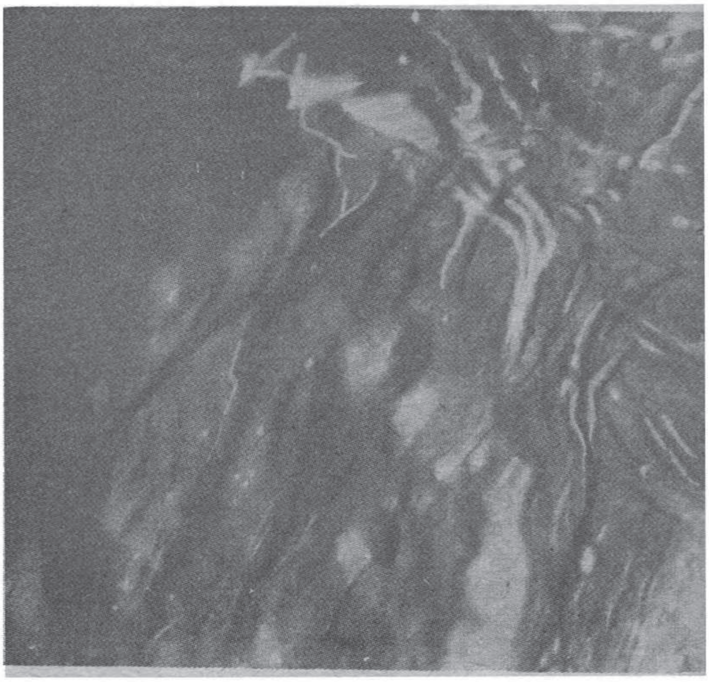
In this highly processed composite picture of Uranus a cloud form can be seen as a bright streak near the planet's limb.



Miranda from a distance of just 31,000 km. This hig
of fractures, grooves and scars. The great variety
different densities of impact craters upon them, si

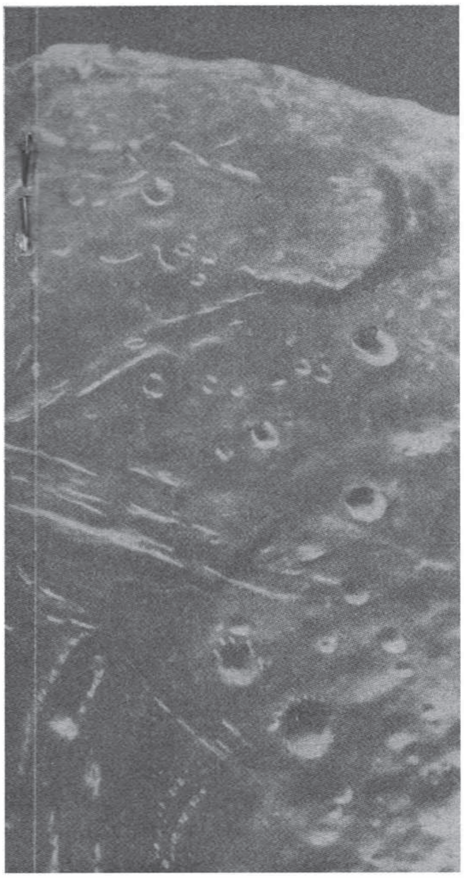


A continuous distribution of small particles throughout the Uranian ring system is revealed in this dramatic picture. This was a time exposure and the streaks are due to trailed stars.



Miranda at close range (36,000 km) displaying two distinct types of terrain –
striated terrain.

ISCOVERY

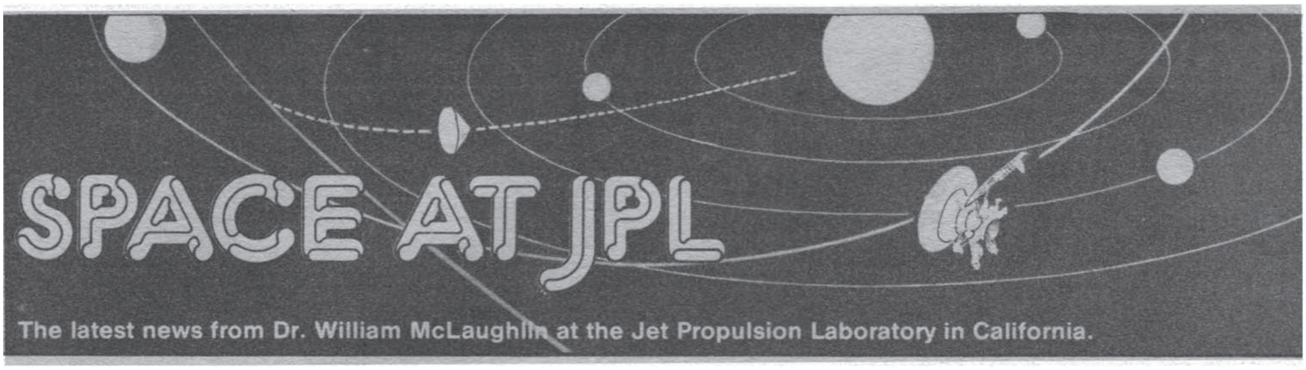


high resolution picture reveals a bewildering variety
riety of directions of fracture and troughs, and the
, signify a long, complex geologic evolution.

in – a rugged, higher-elevation terrain (right) and a lower

A mosaic of the four highest resolution images of Ariel. Numerous valleys and scarps criss-cross the highly pitted terrain.

THE FIRST CLOSE-UP PICTURES FROM URANUS



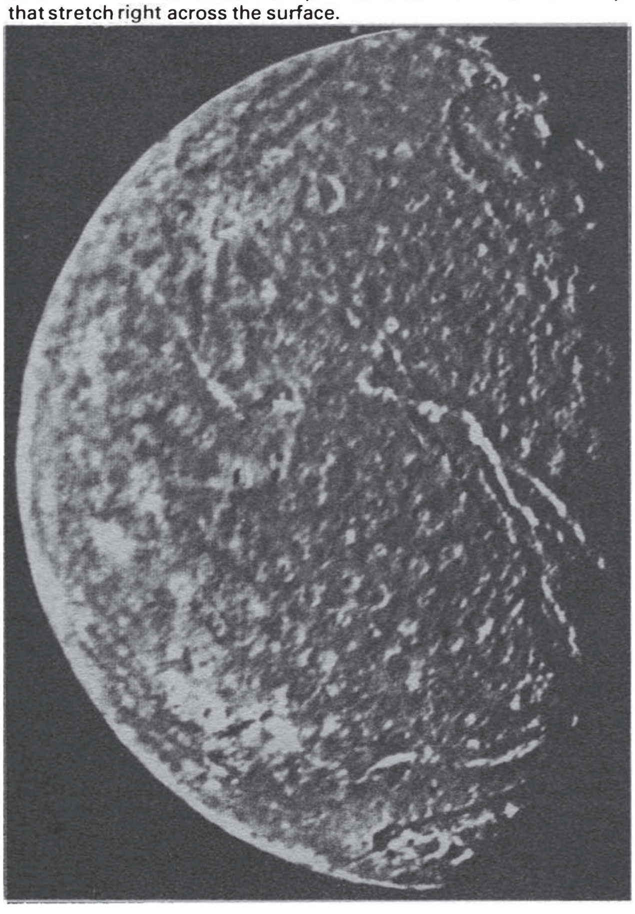
Uranus Discoveries Thrill

Not since the discovery of Uranus by William Herschel in 1781 has so much new scientific information been obtained about Uranus and its satellite system as with the Voyager 2 fly-by. At 17:58:51 GMT on January 24, 1986 the Voyager 2 spacecraft made its closest approach to Uranus, approximately 107,000 km from the centre of the planet, and our fund of planetary knowledge became further enriched.

The highly successful encounter period actually began on November 4, 1985 and extended to February 25, 1986 but the most intense and most important segment of activity occurred in the few hours centered about closest approach (see the November 1985 issue of *Spaceflight* for a Voyager flight plan).

The relative compression of the near-encounter period was due largely to the fact that Uranus lies on its side, with the south pole pointing in a sunward direction. Hence the on-rushing Voyager 2 pierced the plane defined by the planetary equator much as a projectile going through a bullseye target (but slightly off centre, where the planet lies!). Since the rings and satellites are located in the equatorial plane, the spacecraft was closest to almost everything of interest at about the same time.

This is a composite picture of Titania, largest Uranian satellite with a diameter of 1,600 km. The most prominent features are fault valleys that stretch right across the surface.



A detailed review of the scientific results is scheduled for publication in late May in the journal *Science.* A preliminary summary of some of the more important findings is given here.

The planet does possess a significant magnetic field. The most surprising feature of the field is the fact that the magnetic pole is inclined 55 degrees to the rotational pole, so that the field wobbles considerably as the planet rotates on its axis.

The discovery of new bodies included 10 satellites (five were known), one or possibly two rings (9 were known), and several partial rings or arcs. The count may increase as the data are analysed in greater detail.

The Uranian rings appear to be composed of relatively large objects, of the order of a metre or so, and have been swept clean of most small ring particles. However, a long-exposure image with the wide-angle camera, while the rings were backlit by the Sun, revealed dust structures of considerable complexity, resembling images taken at Saturn. Thus, some small particles are present, but not in as great numbers as for the Jovian and Saturnian rings.

The satellite Miranda displayed structures of great variety on its surface. The close approach to that intriguing satellite and the steadiness of the spacecraft while images were being taken yielded some of the most interesting pictures that Voyager has recorded in more than eight years of flight.

Imaging of the other four previously-known satellites also revealed geological structures such as craters, rays, valleys and scarps. Preliminary estimates for these satellites (Oberon, Titania, Umbriel and Ariel) indicate that their density may be in the range of 1.5 to 1.7 gm/cm^3 (water has a density of 1.0 gm/cm^3). Further refinements of these estimates will come when radiometric tracking data have been folded into the analysis. The first new satellite discovered by Voyager 2, 1985U1, was imaged from a distance of about 500,000 km. Features, including craters, were visble on

its surface, and its diameter was estimated to be 170 ± 30 km.

The atmosphere of Uranus showed much less in the way of features than did those of Jupiter and Saturn, but some clouds and other structural features were observed. The temperature profile of the atmosphere as a function of altitude was successfully measured, as was the planetary rotation period (approximately 16.8 ± 0.3 hours – greater accuracy should be achieved upon further analysis), and auroral activity was detected in the atmosphere. An earlier, Earth-based estimate of a very high helium content was not substantiated; the Uranian atmosphere contains 12 ± 4 per cent helium by volume.

With the planned addition of Neptune to the scientific stable in 1989, planetary theorists should have sufficient data to provide definitive models for these residents of the outer Solar System.

A VOYAGER DIARY

The following notes were synthesised from various personal and public records that pertain to the encounter of Voyager 2 with Uranus. The treatment of the encounter is, perforce, sketchy, and the perspective is skewed to my responsibilities as manager of the Flight Engineering Office for the project. Nevertheless it is hoped that some of the flavour of the event can be conveyed through a diary treatment of significant events.

Times are quoted in Pacific Standard Time (PST), which is eight hours earlier than GMT. The number inside parentheses after each date measures the distance of the spacecraft from Uranus at 9 am (PST) in millions of kilometres. Behind the welter of facts and technicalities look for the reaction of the Voyager flight team to the first encounter with Uranus – the thrill of it all!

March 7 1985 (412.1)
First meeting of the Navigational Data Working Group. Wrinkles in new software and hardware installed by the Deep Space Network (DSN) have been resulting in less tracking data with which to estimate our trajectory. I am not concerned for now, but formed the group to ensure we can monitor and influence the performance at encounter.

March 30 (382.7)
Loaded the new dual-processor computer program on Voyager 2. It was briefly tested onboard last fall but will now stay through encounter. Its function is to package the imaging data more efficiently before its transmission to the DSN stations on Earth. By this means we can send back more than twice as many pictures than with the old scheme – an important consideration with the increasing communication distance to Earth.

June 5 (297.1)
The reduced pulse width testing is going well on Voyager 1 (most engineering innovations are tested on the ground and then on this spacecraft prior to use on Voyager 2). This involves making the attitude-control thrusters on the spacecraft fire shorter bursts, by a factor of two, which will result in more gentle control of the spacecraft's orientation. This, in turn, will yield less smear (from "rocking") in the images to be taken at Uranus. It is four times darker at Uranus than Saturn, necessitating longer camera exposure times. During the time the shutter is open we are vulnerable to image smear and consequent loss of resolution.

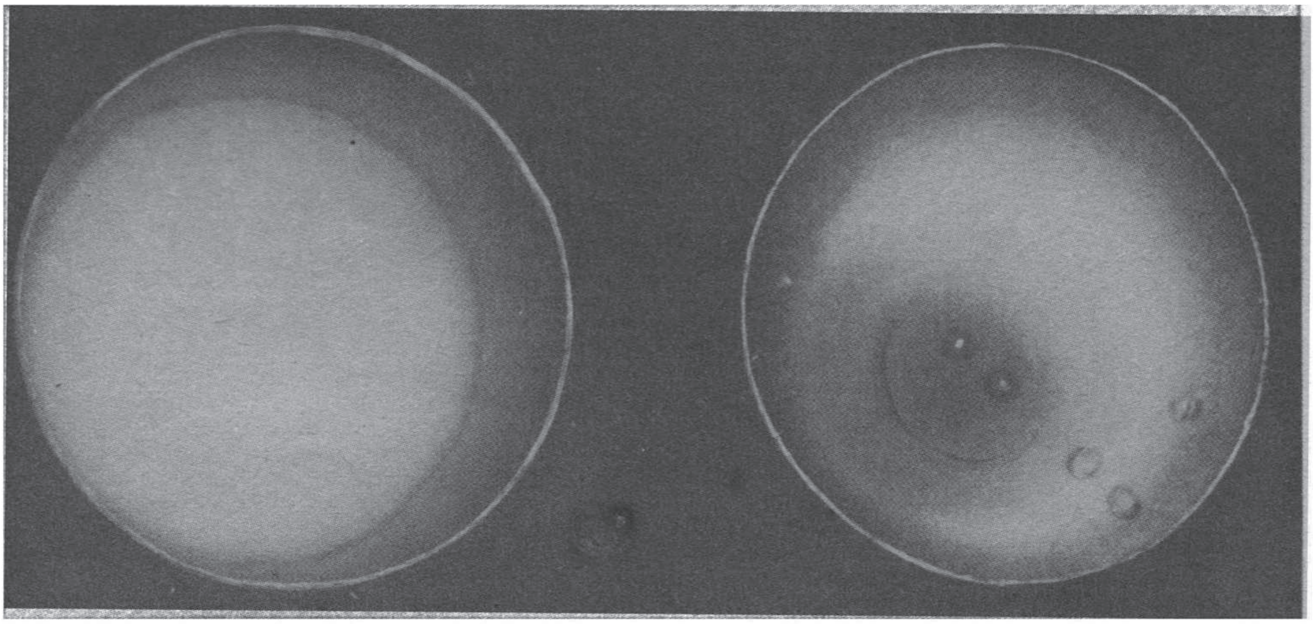
June 13 (286.9)
Looked at the first Voyager 2 optical navigation images we have taken of the Uranian satellites (on June 7). The four larger satellites are visible, but smaller Miranda is still too faint. Now we can start improving the knowledge of the orbit of Uranus and the satellites. I can smell the first wisps of methane from the planet!

July 16 (244.8)
All-day formal review of the project's test and training plan for the encounter. Ray Heacock (a former Voyager project manager) chaired the Review Board, which expressed concern about DSN readiness. I showed statistics from the Navigational Data Working Group.

July 31 (225.7)
Most critical point of testing reduced pulse width on Voyager 2. Went well.

August 6 (218.0)
Dick Laeser (Voyager project manager) and I are in Washington at NASA Headquarters to brief them on Voyager. He outlined science highlights, and I covered engineering. Visited the Air and Space Museum later in the day.

The twin pictures of Uranus were compiled from images returned on January 17 from a distance of 9.1m km. The image on the left would have a green hue and is as the human eye would see the planet from a similar distance. The false colour picture (right) brings out subtle details in the polar regions.



September 9-10-11 (174.7-173.4-172-2)
First test of the all-important Late Stored Updates (LSU) procedure. This flight team activity will take place, for real, in a 30-hour period just before closest approach to Uranus. Then we will utilise the latest navigational data to calculate new pointing, timing, and other critical-parameter changes for cur observations at closest approach. After calculation the new parameters will have to be uplinked quickly to the spacecraft. This test was split into three parts, one done on each day. Fairly smooth performance. No spacecraft commanding included.

October 13 (131.4)
Dr. Charles Stembridge died today. My colleague, who was Manager of the Flight Science Office on Voyager, had fought pancreatic cancer with courage and determination since last year. His contributions at Jupiter and Saturn were great, and he will be missed.

October 24-25 (117.4-116.1)
Near Encounter Test (NET). This simulates on the ground and on Voyager 2 the activity at closest approach: first the LSU by the flight team (see September entry), then the response by the spacecraft. We did not do so well, only getting the changes up to the spacecraft with 10 minutes to spare, but it performed well. We decided to retest the ground activity on November 9.

November 4 (103.4)
The Uranus encounter offically began this morning with some ultraviolet observations.

November 5 (102.1)
Voyager Readiness Review all day. Still concerned about the DSN by the Review Board.

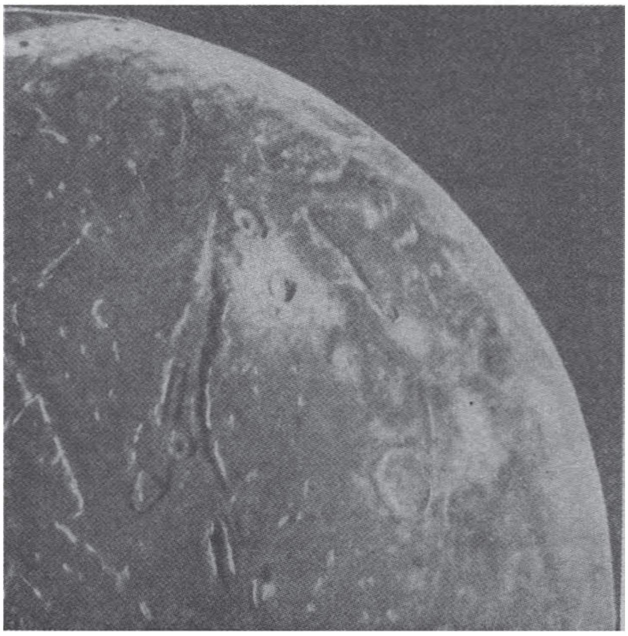
November 8 (98.3)
Surprise; the Epsilon ring of Uranus was seen yesterday on a long-exposure (15 second) optical navigation image. Some had thought the rings were too dark to be seen this early, but I won a dollar bet from Charley Kohlhase (Manager of the Mission Planning Office) that they would be seen this month.

November 9 (97.0)
The retest of the ground portion of the NET went very well.

November 13 (91.9)
Saw Halley's comet for the first time – with 7x35 binoculars. Good luck to Giotto and the others in the Halley fleet.

November 18 (85.6)
Meeting with the navigators to assess our status. I want to get them all together every few weeks to trade ideas. Navigation at Uranus is made more difficult by the great distance (hence less accurate *a priori* satellite and planet orbits), lack of a preceding flight by a Pioneer spacecraft (as occurred at Jupiter and Saturn), and the unusual tipped-pole geometry.

A high resolution picture of Ariel, a Uranian moon with a diameter of 1,300 km. The complexity of Ariel's surface indicates that a variety of geologic processes have occurred.



November 21 (81.7)
No emissions from Uranus have been detected by the Planetary Radio Astronomy experiment yet; one consequence is that we probably will not see a strong magnetic field at Uranus. This would also imply a low-intensity radiation environment. Good! Spacecraft computers can malfunction if the radiation levels get too high.

November 28 (72.8)
Late in the evening my wife Karen and I went to JPL to watch long-exposure images being returned from Voyager 2. We saw the Epsilon ring clearly. The Imaging Team says that our reduced pulse width effort has paid off with the ability to produce these images.

December 2 (67.7)
Meeting on advanced planning for Neptune. Even though we are nearing Uranus, the drum is starting to beat for the 1989 flyby of Neptune.

December 9 (58.8)
Voyager 2 is behind the Sun today. Relativity and solar corona experiments are being done in this period of time (few weeks), using the X-band and S-band radio systems.

December 13 (53.7)
Important milestone as flight team representatives met to discuss the changes we want to make to our closest approach observations. We were able to fit almost all desired scientific and engineering updates into these modifications. The observations will fill the few days around closest approach and will be optimised later by the LSU. The changes proposed today are conceptual ones driven by thought and Voyager 2 observations over the past few week.

December 16 (49.9)
Voyager Family Night at the Laboratory in the evening. Spouses and children saw movies and heard a talk by Ed Stone about Uranus. They also got to see the flight team Mission Support Area.

December 20 (44.8)
The Navigation Team thinks that the mass of Uranus is 0.3 per cent greater than previously expected. Consequently we will move the aim point a few hundred kilometres outward from Uranus in order to achieve the desired gravity assist to Neptune. Some relative timing changes will result in the observations of Uranus. The Science Office has been briefed.

December 23 (41.0)
Trajectory correction manoeuvre went well. The velocity change was 2.1 metres per second. The spacecraft was off Earth-point for the manoeuvre and communications were thus interrupted. A dramatic reminder of its return to Earth-point took place when all the line printers started their chorus of chatter again, recording the restoration of spacecraft telemetry.

December 25 (38.4)
Ham for Christmas dinner. Took the day off from work. The whole family looked at Halley through our 4-inch reflector. All four Galilean satellites were also visible about Jupiter.

December 31 (30.8)
The unofficial word through the project today is that a new satellite of Uranus was discovered in earlier images. Confirmation awaited.

January 3, 1986 (27.0)
The IRIS (infrared experiment) instrument returned anomalous data from its recent health check. It has a history of problems, but this seems to be a new trouble. Considerable concern exists.

January 4 (25.7)
The PPS (photopolarimeter) decided to misbehave today. It did not go to the proper-sized field of view upon command. This is an old problem with the PPS. We spent most of the day analysing the situation and started corrective action.

January 7 (21.9)
More data have been analysed concerning the IRIS problem. My impression after talking with the instrument people is that the experiment will execute satisfactorily at Uranus.

Third meeting of the navigation discussion group today (see September 18). We are seeing a slight drift in successive trajectory estimates which may indicate an unmodelled force, but generally things are going well. We know the arrival time at Uranus to within about 70 seconds now. The delivery position with regard to the Miranda flyby is now known to 500 or 600 km; by closest approach we have to have that down to 100 km for accurate pointing.

January 9 (19.3)

The new satellite discovery has been released to the press; this is the sixth satellite for Uranus. A seventh and eighth are in the process of being confirmed prior to public release. A composite image of the atmospheric features seen to date is also ready for release. With a dark area around the pole it looks like a giant eye in the sky. The drift in successive trajectory estimates continued and has become a source of worry.

January 13 (14.2)

Check of the IRIS instrument showed that it is now working well!

January 15 (11.7)

Navigational Discussion Group met in the morning. The drift in trajectory estimates has stopped, and we are just getting stochastic fluctuations in the estimates as we add more optical and radiometric date. We held an operations strategy review all afternoon. Went over the plans for next week's near encounter events. The important IRIS observation of the infrared output of Uranus seems to have gone well. This will factor into an eventual compilation of the heat balance of the planet.

January 16 (10.4)

The discovery of six new satellites was announced today. Uranus now has 12 of them. Special Nav Working Group meeting showed that the last weeks of DSN tracking data have been excellent, about 90 per cent of it is usable. Now we have to hold this performance through encounter. Reviewed our last Far Encounter sequence load before uplinking it to the spacecraft tomorrow. We are closing in!

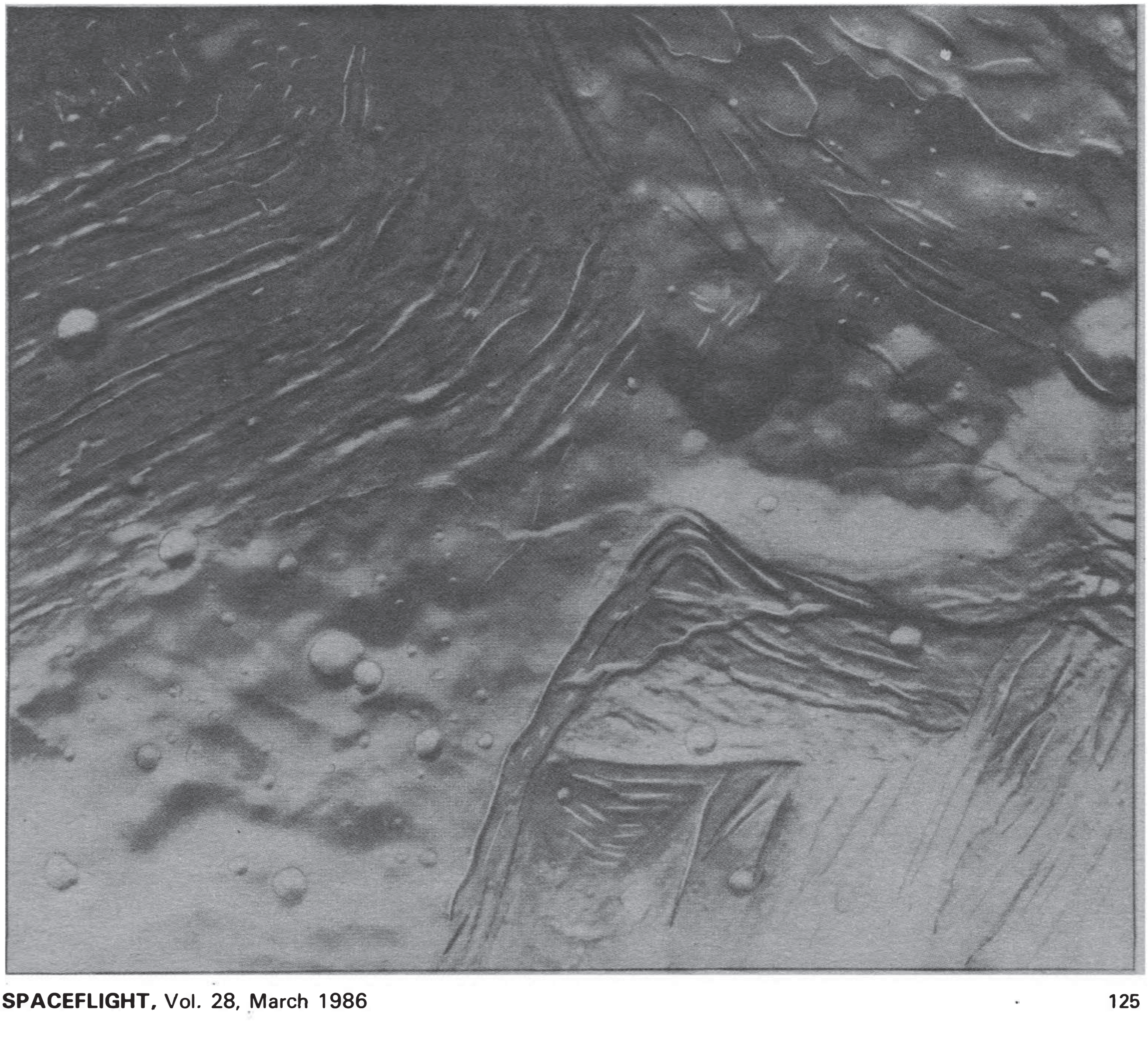
January 17 (9.1)

We cancelled the trajectory correction manoeuvre scheduled for Sunday; the first time an encounter manoeuvre has been cancelled on Voyager. The course is so close to where we want to go that there is no reason to touch it up. The benefits from not doing it up are fourfold: (1) the tracking – date blackout for a day or so after a trajectory correction manoeuvre on Voyager 2 will be avoided (the Voyager 2 receiver has a reduced bandwidth due to a failed capacitor and cannot be locked onto after certain thermal events), (2) we do not introduce a propulsive "bump" into the ongoing orbit determination process, (3) the small but always-present risk of such an event is avoided, (4) the workload for the flight team is reduced considerably.

January 18 (7.8)

White and dark lines have started appearing in many of the Voyager 2 images. We have an analysis meeting scheduled for early tomorrow.

This image of Miranda shows an unusual "chevron" figure and regions of distinctly differing terrain. Taken at a distance of 42,000 km the picture spans an area about 220 km across.



January 19 (6.6)
Analysis of the performance of the ground system has uncovered no problems, indicating that the problem is the images may be onboard the spacecraft. We spent the day generating commands to send the Voyager 2 to read out one of its computer memories which, from the symptoms, is suspect. About midnight the read out came to Earth (5½ hour round trip light time to Uranus) and showed that one bit in one word in the memory was "1" when it should be "0". We will fix it tomorrow. At 3 am my Deputy Manager (Donna Wolff) and I watched the last diagnostic test of the scan platform gear mechanism on Voyager 2. That gear mechanism malfunctioned just after the closest approach at Saturn, and we have been using it carefully and monitoring it closely ever since. If the diagnostic test failed, we would use an already-prepared alternative sequence load at Uranus closest approach, one which would not employ the once-faulty gear but use instead motion of the entire spacecraft to help point the remote-sensing instruments. Fortunately, the mechanism worked perfectly and we endorsed the normal use of the scan platform for the next few days of crucial observations.
January 20 (5.3)
Decided to modify the onboard computer program to avoid the bad bit and, at the same time, to see if we could change it back from "1" to "0". By midnight the results were back; the correction has been made but the bit did not flip, so it is a hardware failure – no big problem for only one word of memory. The pictures should be cleared up tomorrow. Six of the nine known rings are now easily visible on the TV monitor on my desk.
Januarty 21 (4.0)
I held an Engineering Office staff meeting today to check our status before the critical activities of the next few days. The spacecraft is healthy and producing good images after yesterday's repair. Navigation looks solid; the relative uncertainty between the spacecraft and Miranda is down to about 200 km. For pointing the cameras, we need to achieve 100 km or less and appear to be on the way to accomplishing this figure. The Sequence Team has got our computer load for closest-approach observations almost done. Kelly Beatty of *Sky and Telescope* magazine dropped in to discuss the encounter. Press interviews are increasing.
January 22 (2.7)
The Uranian satellites are growing in size on my TV monitor and starting to show features. How often does one get to observe the approach of a new world? In the evening we started the all-important Late Stored Update (LSU) (see September 9). The Navigation Team will process optical and radiometric tracking data all night. Donna has the watch overnight.
January 23 (1.4)
I have the watch today. We had a well-attended meeting at 5 am to evaluate the navigational results. They look great! Our knowledge of the trajectory is turning out to be better than expected. The Spacecraft and Sequence Teams started to work processing the navigational results to modify the timing and pointing parameters in the program onboard Voyager 2. The Navigation Team continues to process tracking data for further refinements. By midnight we were done with the LSU and the modifications to Voyager 2 at 1:15 am. The Navigation Team really nailed the trajectory, with an uncertainty between the spacecraft and Miranda within 50 km. Lack of engineering excitement has never been so welcome. Got to bed at 2 am.
January 24 (as close as 107,000 km today)
This is it – the big day. I arrived at JPL early, and, generally, all was progressing as expected. However, Howard Marderness (Spacecraft Team Chief) reported that we had seen one cycle error in the attitude control computer. This will not have an effect but could be serious if it persists. It means the computer is overly busy. The phenomenon did not occur at the Near Encounter Test (October 24) but we have made slight changes to the observing program since then. Just before I was ready to give a TV interview at 4 pm, the "beeper" on my belt sounded. But after a quick check with the Spacecraft Team the news was good; the cycle errors (there had been four more) were benign and we should be OK. The interview was, consequently, quite a nice event for me. Voyager 2 slid behind Uranus, and continued its experiments. We could detect its existence through radio waves that it was beaming through the Uranian atmosphere to probe the structure of that entity. The DSN was performing magnificently. The spacecraft emerged from occulation about 4:30 pm. The telemetry was not turned on for another two hours (to facilitate a radio science experiment measuring ring structure). When it did come back on all systems were in excellent condition. We did it! Tomorrow the pictures will be replayed from the tape recorder and we will begin to see what the rings, satellites, and surface of the planet really look like. In the early evening, several of us sat in the project office, listening to the mission and looking at data, but mostly we had begun to relax from the tension of the last few weeks.
January 25
Today, in effect, we went through the Uranian system for a second time as the pictures were replayed. What a feast! Miranda is proving to be the real star of the show. Karen and three of our four children joined me as other visitors and guests from around the world converged on JPL.
January 26
At today's press conference, the scientists commented on how crisp and clear the images were and expressed their approval of the smear reduction measures we had taken to steady the spacecraft as an observing platform. Our pointing also turned out to be near perfect, and we captured the most difficult target of all: nearby (29,000 km) Miranda. It was certainly worth the effort, for geologist Dr. Larry Soderblom described the satellite as a "bizarre hybrid" of geological forms and one of the most interesting objects in the Solar System.
January 27
I had not been able to get with Len Carter yesterday; he was here as a guest of the Laboratory to observe the encounter. But this morning we met and went to visit Dr. Lew Allen, Laboratory Director. The sky is blue in Southern California today and the temperature is about 80 degrees, but I think the warm glow from the encounter is what I feel most.

The southern hemisphere of Umbriel displays heavy cratering in the image taken from a distance of 557,000 km. Umbriel is the darkest of Uranus' larger moons and appears to have experienced the lowest level of geological activity. The strangest feature on this image is a curious bright ring. Its nature is not known, although it may be a frost deposit, perhaps associated with a large impact crater.

COMET FLY-BY FIRST RESULTS

by L. J. Carter

The International Cometary Explorer (ICE) crossed the tail of Comet Giacobini-Zinner on September 11, 1985 becoming the first ever spacecraft to intercept a comet. The encounter produced a rich harvest of information about the interaction between the comet's atmosphere and the solar wind.

Scientific findings from the fly-by of Giacobini-Zinner by the American ICE spacecraft confirmed the traditional portrait of a comet and yielded much new information.

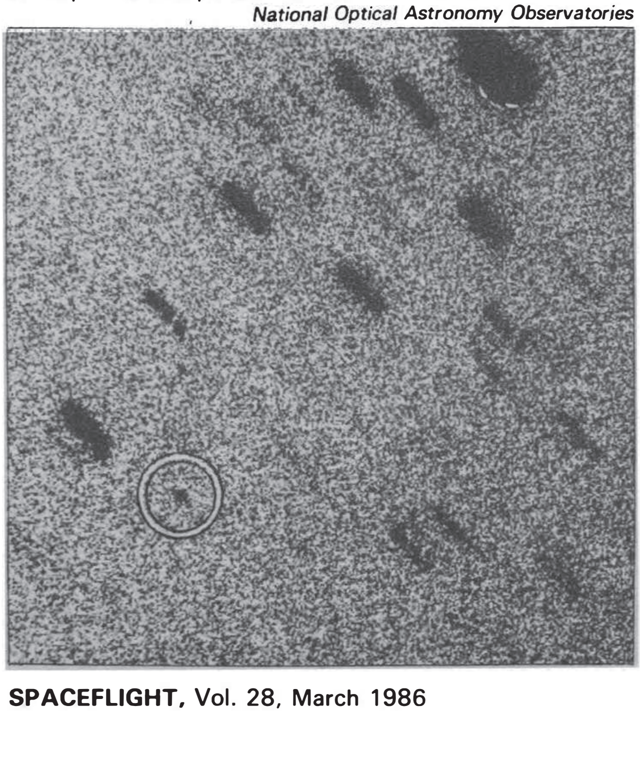
Among unexpected measurements were the spatial extent and intensities of the energetic cometary ions found by the Energetic Particle Instrument. Signs of these were detected much further out than expected at a distance of more than one million km before closest approach.

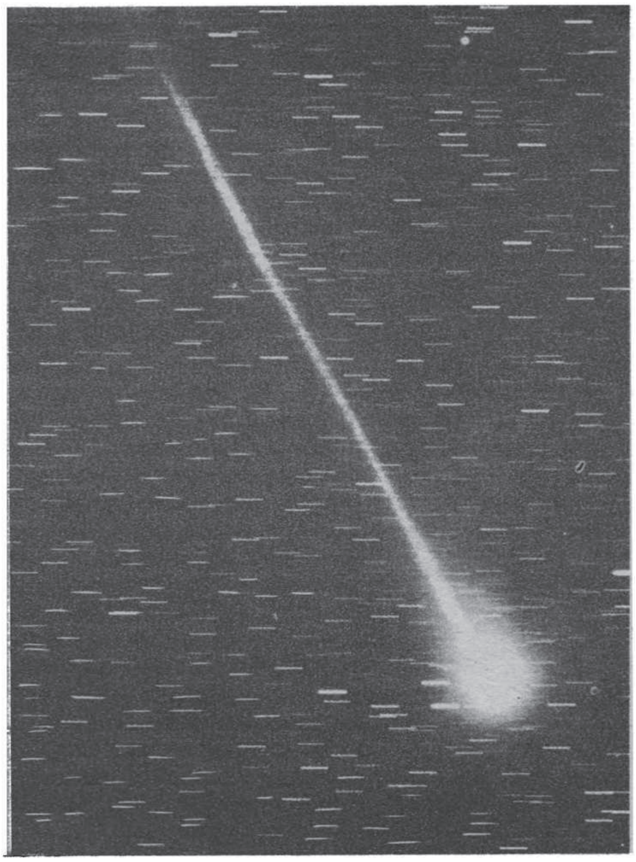
The spacecraft payload had originally been designed to measure the solar wind, solar X-rays, energetic charged particles and the composition of galactic cosmic rays.

So, of the 13 instruments onboard, seven were selected on the basis of returning the most useful data during the cometary encounter and these were: Electron plasma, Magnetometer, Plasma waves, Radio waves, Plasma composition, Low-energy cosmic rays, and Energetic particles.

Prior to encounter it had to be decided on the exact trajectory through the comet's plasma tail.

The recovery of Giacobini-Zinner on 3 April 1984, from the Kitt Peak National Observatory by S. Djovgovski and H. Spinrad (University of California, Berkeley), and G. Will and M.J.S. Belton (Kitt Peak National Observatory). The elongated images are stars smeared out as the telescope tracks the predicted motion of the comet.
National Optical Astronomy Observatories





Comet Giacobini-Zinner, with its ion tail, is shown in this 26 October 1959 photograph by Elizabeth Roemer. *US Naval Observatory*

An aiming point far down the tail carried the risk of missing it altogether due to the 'wagging' effect in response to variations in the velocity of the solar wind.

And aiming too close to the nucleus would have created a potentially serious dust hazard. As a compromise interception of the tail was planned at 10,000 km from the nucleus but a minor orbital trim manoeuvre on September 8 to take account of the latest information on the comet's position reduced the actual flyby distance to around 8,000 km.

The cometary presence was first noticed in the energetic ion data about 24 hours prior to closest approach and some kind of 'bow shock' wave was detected early on September 11. However, the characteristics were quite different from the bow shock observed in front of planets like the Earth and Venus.

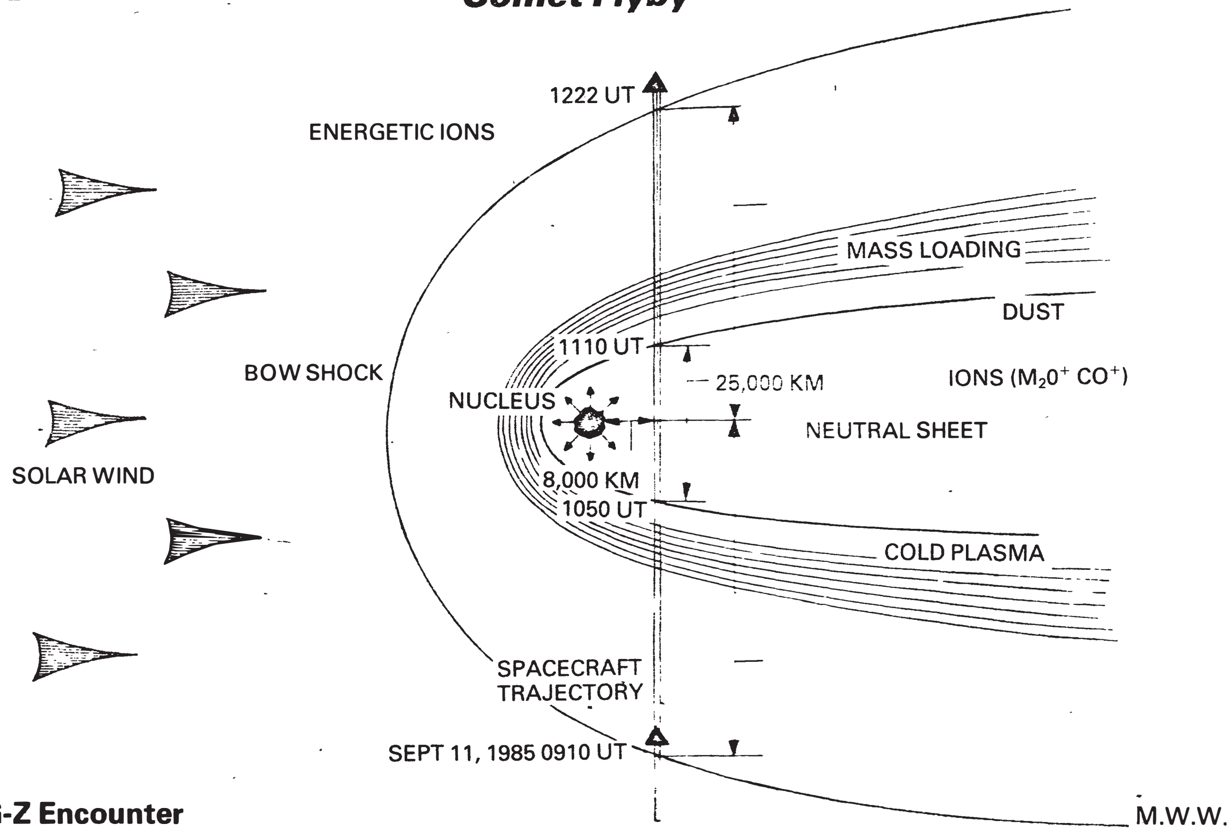
Sudden changes in the magnetgic field were not clearly detected and no distinct point was found where the plasma density rose to higher values inside than outside. The high mass density of cometary heavy ions may cause this unexpected structure but the true nature of the cometary 'bow shock' remains open.

As the time of closest approach drew closer the ICE spacecraft traversed a region of turbulence (known as the "interaction region") where assimilation between cometary ions and solar wind plasma takes place.

The turbulence decreased before ICE entered the cold plasma tail where cometary plasma of high density and low energy dominated.

The outward pass revealed similar characteristics to the inward one, including the 'bow shock' structure. Total width of the cometary interaction region between the shock boundaries was found to be 250,000 km, 140,000 km on the inward pass and 100,000 km on the outward.

A major prediction confirmed by the ICE data was



ICE G-Z Encounter

that the magnetic structure of the comet's plasma tail consisted of two parallel lobes, each threaded by a magnetic field of opposite polarity – a structure suggested by Dr. Hannes Alfven in 1957.

One of the most unexpected results was that neither the spacecraft nor its instrument payload suffered damage as a result of impact with cometary dust.

ICE did not carry a specific dust experiment but it was possible to deduce information on dust impacts from the plasma wave detector data. Micron-sized particles were recorded during the crossing of the plasma tail, with a peak in the impact rate near the point of closest approach.

Comet Giacobini-Zinner, with a short period of 6.5 years, is a member of the Jupiter family of comets. It was discovered by M. Giacobini at Nice, France, in 1900 and rediscovered by E. Zinner at Bamberg, Germany, 13 years later.

By 1985 it was at its 11th observed apparition, reaching eighth magnitude at its brightest. The comet has a fairly stable orbit inclined at about 30 degress to the ecliptic, though discontinuities in its orbital motion, probably caused by outgassing (jets), qualify it as an "erratic" comet.

Studies suggest that it has a highly flattened nucleus with an equatorialdiameter of 2.5 km, which is some eight times larger than its polar diameter.

This flattened nucleus seems to be spinning rapidly, making a complete rotation every 1.66 hours – close to the critical rate at which an oddly-shaped iceball could, literally, break into pieces.

The success of ICE's encounter with Comet Giacobini-Zinner has given officials at NASA cause for optimism that the spacecraft will be able to collect useful scientific data about Halley's comet.

Scientists say there is now a good chance that the spacecraft will be able to measure particles from Halley's comet at the end of March and during the first week of April.

Sun Explorer Turns to ICE

When the International Sun-Earth Explorer 3 (ISEE-3) was launched in August 1978 there were no plans for cometary encounters – its mission was to collect scientific data about the solar wind and study the Earth's magnetosphere.

However, the spacecraft remained in good operational condition on completion of its three year mission and in June 1982 was diverted by NASA controllers to study the Earth's magnetotail.

Then, in March 1983, began a series of spectacular orbital manoeuvres for ISEE-3 computed by Dr. Robert Furquhar and his team of engineers at NASA's Goddard Flight Center.

The spacecraft traced a series of complex curves, diving from deep outer space to within a mere 120 km of the Moon's surface on the final occasion before being catapulted out towards Comet Giacobini-Zinner. It was at this point the probe's name was formally changed to International Cometary Explorer (ICE).

But the historic 'first' may not be the end for this remarkable spacecraft. After passing within 32 million miles of Comet Halley at the end of March it will continue out on an elliptical orbit.

That orbit will return ICE to the vicinity of the Earth in the year 2012 and Furquhar predicts, with some excitement, that a gravity assist manoeuvre using the Moon could place it into an Earth orbit.

From here, the Space Station complex and an Orbital Transfer Vehicle might then be able to retrieve it and return it to the Earth for examination and display!

Compiled by L. J. Carter

COMET STAMP COLLECTION GROWS

Stamps commemorating the return of Halley's comet are currently being released by more than 20 different countries from around the world.

The British Post Office set were released on February 18 and the four stamps feature paintings of the comet at various stages of its return to the vicinity of the Sun (see ***Spaceflight,*** February 1986).

Other countries which have already released commemorative stamps include Ascension Island, Bermuda, British Antarctic Territory, Hong Kong, Jersey, Malawi, Mauritius, Seychelles and Swaziland.

Those countries still to publish their special stamps include Australia (April 9), Botswana (March 28), Fiji (July), Micronesia (March), Norfolk Island (March 11), Papua New Guinea (May) Samoa (April), St Helena (May), Sri Lanka (March), Tristan da Cunha (March), and Solomon Islands, Trinidad and Tobago, Vanuatu and Zambia (dates to be announced).

Books Galore

The number of books on comets (many specifically on Halley's comet) which have appeared over the past year is now approaching 50.

It is impossible to keep pace with all these but a further batch of reviews of some of the more important works appears below.

Mankind's Comet

G. Ottewell and F. Schaaf, Astronomical Workshop, Furman University Greenville, S.C. 29613, USA, 15 x 11 in. 1985, 193pp $22.00.

This is a good addition to any collection on Halley's comet for it contains several unusual features both in presentation and content.

Sub-titled "Halley's Comet, in the past, the future and especially the present", this is probably the largest-sized book devoted solely to the comet which has yet appeared. Although directed to the layman, it contains much historical material not covered elsewhere, e.g. references to events contemporary to the non-observed appearances of the comet between 315 BC and 140 BC. All the subsequent recorded appearances are dealt with in turn, and most interesting they are. This digest is followed by descriptive text of comets in general, drawing attention to many characteristics both of comets and meteors.

Considerable information is given about the 1910 return and the authors also describe the current "space fleet" of cometary probes.

Particularly interesting is one of the appendices which is an Atlas of the 48 visits computed for the comet from 140 BC to AD 2133. Charts show the movements of the comet at each return against the stellar background, as seen from Earth, though only the charts for 1404 BC and 1986 are fully labelled.

Comet

G. Walz-Chojnacki, AstroMedia, a division of Kalmbach Publishing Co., 625 East St. Paul Ave, P.O.Box 92788, Milwaukee, WI 53202, 64pp. $9.75.

Sub-titled "The Story behind Halley's Comet" this book sets out to provide, for the younger reader, a simple explanation of comets and their effects on mankind, ending with a series of star maps, tips on observation and several projects on comets and meteors.

The book, beautifully illustrated and very easy to read, should meet the needs of its potential readers admirably.

Comet Watch: The Return of Halley's Comet

Frank H. Winter, Lerner Publications Company, 241 First Avenue North, Minneapolis, Minnesota 55401 USA, 1985, 64pp, U.S.$9.95.

This is a book on Halley's comet which a young reader will not fail to find interesting. It explores the fascinating characteristics of the famous fiery, mysterious object that has played such an important role in human history beginning with an account of early beliefs that comets were warnings of impending disasters and going on to explain how the work of Halley marked a turning point in comet history. The author also describes preparations being made around the world for the 1985-6 return.

The book is well illustrated, easy to read and, as one might expect from such an author, very well researched.

Some of the recently introduced stamps commemorating the return of Comet Halley.

Halley's Comet

M.E. Bailey, Department of Astronomy, The University, Manchester, M13 9PL, 1985, 90pp, £1.50.

The author set himself the task of finding a reliable yet non-wordy guide to Halley's comet. Finding none suitable, he prepared this short introduction to comets generally and to the 1985-6 sighting of Halley's comet in particular, including finding charts and hints on how best to observe the comet.

Oberserver's Guide to Halley's Comet
J. Muirden, George Phillip, 12-14 Long Acre, London WC2E 9LP, 73pp, 1985, £2.95.

This handy paperback is an easy guide for anyone interested in observing Halley's comet. It includes advice on finding the Comet with the naked eye, bionoculars or telescopes. It is illustrated with month-by-month star maps while tables for each month give details of the comet's rising and setting times and altitudes.

Halley's Comet: Memories of 1910

R. Etter and S. Schneider, Abbeville Press Inc, 505 Park Avenue, New York, N.Y. 10022, USA, 1985, 96pp, $19.65.

The authors spent years accumulating what they call a whimsical collection of Halley's comet memorabilia, all dating back to 1910 and a collection which has now grown to the point that it is acknowledged to be the largest in the world.

This is amply borne out by the present volume, containing 200 illustrations in colour and which amounts to a fabulous potpourri of artefacts to do with the comet from bracelets, buttons, telegrams and compacts to cartoons, newspaper clippings, advertising, souvenirs, song sheets and a marvellous collection of over a hundred post-cards. It even includes childrens' games, silver pieces and the first Delft commemorative plate!

Comets, Meteors and Asteroids: How they affect Earth

S. Gibilisco, John Wiley & Sons, Shripney, Bognor Regis, West Sussex, PO22 9SA, 1985, 208pp, £11.45.

Impact craters on many worlds show that meteors, and possibly comets, must have also affected the Earth in bygone years. From this it is only a short step to consider how such events could have altered the Earth's climate and even the evolution of life.

The author pays particular attention to the latter and considers whether such impacts could have caused the demise of the dinosaurs or changed the geographical orientation of the Earth's axis.

He traces events from the big bang theory of the origin of the Universe to the leftovers from the formation of the Solar System. Considerable space is given to the treatment of comets, such as their possible origins, lifetimes and probable ends.

A further chapter discusses Halley's comet, while another introduces the topic of comet-hunting for amateurs. This is followed by a similar chapter on meteors/meteorites before ending on such speculataive matters as whether and how comets contributed to the origin of life on Earth.

KEEP UP TO DATE

The Halley Comet "Hotline" is concentrating on the progress of Giotto. Regular reports can be obtained from dialing the following numbers:

Belfast	**0232-230-505**	**Birmingham**	**021-355-6144**
Bristol	**0272-279-494**	**Cardiff**	**0222-399855**
Glasgow	**041-552-6300**	**Leeds**	**0532-8013**
Liverpool	**051-236-8474**	**London**	**01-790-3400**
Manchester	**061-246-8061**		

TELESCOPE DETECTS ICE

Solid ice particles have been detected in Halley's comet, confirming for the first time the theory that comets consist largely of ice.

The idea that comets are "dirty snowballs" was first presented in the 1950's but direct evidence for the existence of ice has always been missing.

Observations made at the Lick Observatory allowed astronomers to penetrate the gas cloud surrounding Halley's comet to a region where ice grains exist intact. There they detected a characteristic infrared signature from the ice grains.

The observations were made with the Observatory's 3-meter Shane Telescope on the nights of November 5 and 6, 1985. Discovery proved possible because of good timing and the use of a special spectrometer recently developed at Ames Research Center. A spectrum was made by passing sunlight reflected by the comet through this spectrometer – ice grains in the comet absorbed some of the Sun's infrared energy, leaving a tell-tale feature in the spectrum.

"We were able to see down to where snowflakes were coming off the comet," said David Rank, Lick Observatory astronomer and UC Santa Cruz professor of astronomy.

Timing of the observation was critical. Had the comet been too far from the Sun there would not have been enough reflected sunlight to give a strong signal: had it been too near, its own infrared emission would have completely masked the absorption feature of the ice grains in the spectrum.

Astronomers had long supposed that ice was present in comets because they observed gaseous hydrogen and oxygen compounds – presumed to be by-products from the breakdown of the ice in the cloud, or coma, surrounding and hiding the comet's nucleus.

In 1983, observations of Comet Cernis by Martha Hanner of JPL indicated the presence of ice grains but her work involved measuring the brightness of the comet in three regions around the ice grain absorption feature and discovering decreased brightness in one of the regions. The Lick-Ames group is the first to reveal a spectrum that clearly shows the absorption feature at the wavelength at which ice grains are known to absorb infrared light.

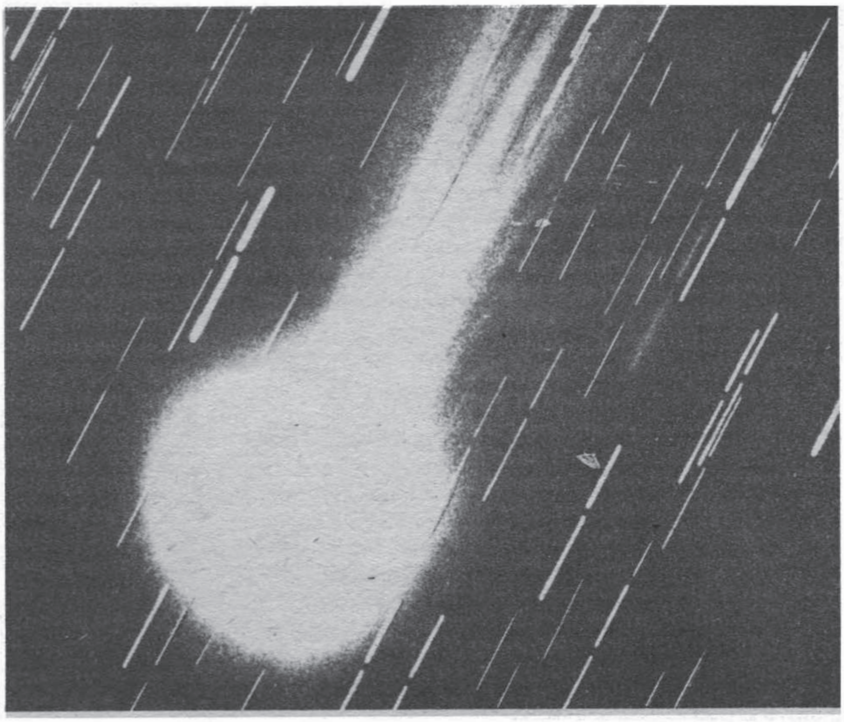
Attempts will be made to observe this absorption feature, called an "ice band" in other comets as well so that its exact shape can be pinned down and deductions made on the exact composition of the ice. Since comets are thought to be primordial material left over from the Solar System's formation period, their exact composition is of great interest.

NEW TASK FOR GIOTTO

Giotto, with only 12 per cent of its onboard stock of hydrazine used and now likely to survive the Halley's comet encounter undamaged, seems in good shape to accomplish a second mission.

No studies have yet been made for a second mission but there is plenty of time for these to be done. A suitable candidate could be Comet Schwassman-Wachman 3, a very faint object discovered photographically in 1930 and with a period of six years.

HALLEY'S COMET STARTS A TAIL



Halley's comet photographed on December 9, 1985 with the Anglo-Australian Telescope at Coonabarabran, New South Wales, Australia. The telescope followed the comet's motion during the exposure, so that all stars appear as lines.

As the comet approached the Sun, gas and dust were freed from the icy nucleus to form the bright head and tail which now appear to an observer on Earth.

The pressure of radiation from the Sun on the tenuous head sweeps some of the material, away to form the tail, which is seen stretching to the right.

Individual streamers in the tail are believed to originate from different spots on the nucleus.

PIONEER OBSERVATIONS

NASA's Pioneer spacecraft, still orbiting the planet Venus, began six weeks of observations of Halley's comet during the comet's most active period closest to the Sun (perihelion).

Observations in the ultraviolet spectrum began on December 26, 1985 the first phase ending on January 4 when both Venus and Pioneer passed behind the Sun for almost a month, cutting off effective communictions between the spacecraft and ground controllers at NASA's Ames Research Center, Mountain View, California. Observations resumed on February 3, six days before perihelion, and continues until March 6.

Near the time of perihelion, the comet, Venus and Pioneer were all located on the opposite side of the Sun, some 160 million miles away from Earth. Pioneer was the only spacecraft close to Halley's comet at this time.

It is hoped that Pioneer's observations will reveal the rate of change of comet outbursts and evaporation with time, the composition of the coma (gas and dust cloud around the comet nucleus), and the extent of the hydrogen cloud. Other data may show the shape of the coma and its gas/dust ratio.

This was Pioneer's third look at a comet. It viewed Comet Encke in mid-1984 and Comet Giacobini-Zinner in September 1985. Somewhat surprising data showed that Comet Encke was losing water at a rate of three times greater than expected for its distance from the Sun.

Pioneer spins on its axis five times a minute as it journeys in orbit around Venus. By choosing the number, length and direction of thruster pulses, engineers can tilt this axis to any desired position. For the Halley's comet observation, the spin axis was moved in small increments by firing some 1,000 pulses, each of half-second in duration. The entire manoeuvre consumed nearly half of the spacecraft's usable fuel reserve.

Because the spectrometer has a small field of view and is always rotating, it "saw" only a strip of Halley's comet during each spin. However, by tipping Pioneer so the spectrometer could view another area, a two-dimensional image of the entire comet was developed, strip by strip.

ULTRAVIOLET INVESTIGATIONS

The first observations from space of Comet Halley were made with the International Ultraviolet Explorer spacecraft (IUE) back in April 1985 and in December a further, more intensive cycle of observations started which will last until the comet has returned to the outer regions of the Solar System.

In total more than 150 hours of observing time will be dedicated tc observations of Comet Halley with the IUE Observatory satellite.

Spectra taken with IUE in the Ultraviolet on December 15, 1985 when the comet was at a distance of 115 million km from the Earth showed clear evidence of a considerable increase in activity in the comet caused by the enhanced solar radiation.

The results obtained showed that in this relatively young periodic comet the gas composition is similar to that found in other older comets observed earlier with the IUE spacecraft. The characteristic emission of the elements hydrogen, carbon, oxygen and sulphur as well as the emission of molecules such as carbon-sulphide and the possible decomposition product of water, hydroxyl, were identified.

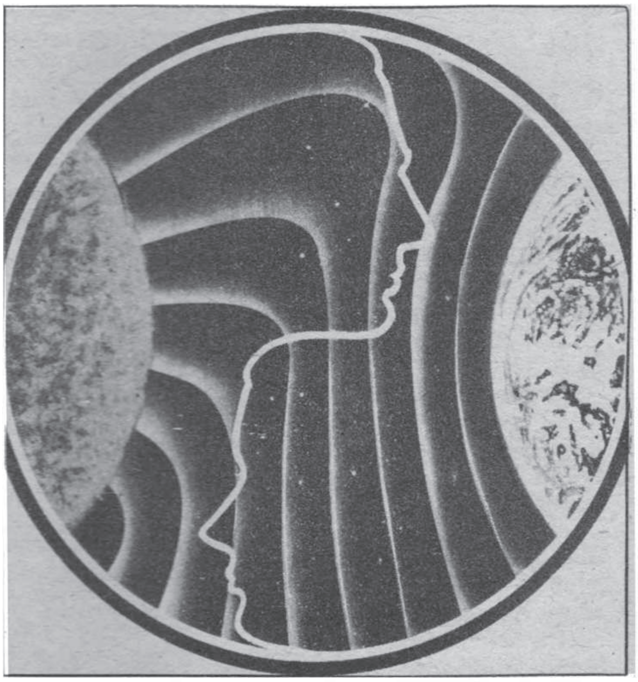
The production of gaseous material increased substantially as Halley approached the Sun – in December the gas production rate was more than five times higher than that observed in September.

The comet has a significant dust cloud (dust Coma) with it. The dust coma is rather compact (20 000 km; this is only one tenth of its gas coma) and appears quite dense. This could be of importance to the success of ESA's Giotto mission which is coming very close to the cometary nucleus and will pass through this dust cloud to obtain pictures of the cometary nucleus.

THE GEOSPACE SCIENCE MISSION

By John Bird

Over the next few decades, scientists studying the near-Earth space environment will be attempting to develop a comprehensive understanding of its interactive regions, including the magnetosphere and the ionosphere. These regions around the Earth are known collectively as 'geospace'.



The International Solar Terrestrial Physics programme will study the Earth's environment in unprecedented detail. *NASA*

Introduction

The ambitious goal of understanding geospace in detail can be realised only by using a large network of observation stations on the ground and in space. By taking simultaneous complementary observations in many locations, it will be possible to piece together the puzzle of this complex system. The International Solar Terrestrial Physics programme is being developed by NASA, the European Space Agency, and the Institute of Space and Astronautical Science (ISAS) of Japan to commence in 1989. A comprehensive study of geospace as a whole has not been previously attempted.

A key element is the Global Geospace Science (GGS) mission, involving four complementary satellites. They will be in different orbits and will be capable of making large changes to move to new paths. The scientific objectives include tracking of particle and energy flows from the solar wind to our atmosphere, determination of the influence of plasma processes and investigation of the origin and loss of plasma near the Earth. Plasma is a gas in which the atoms are electrically charged, or ionized. In addition, theoretical work will involve the synthesis of mathematical models to simulate geospace.

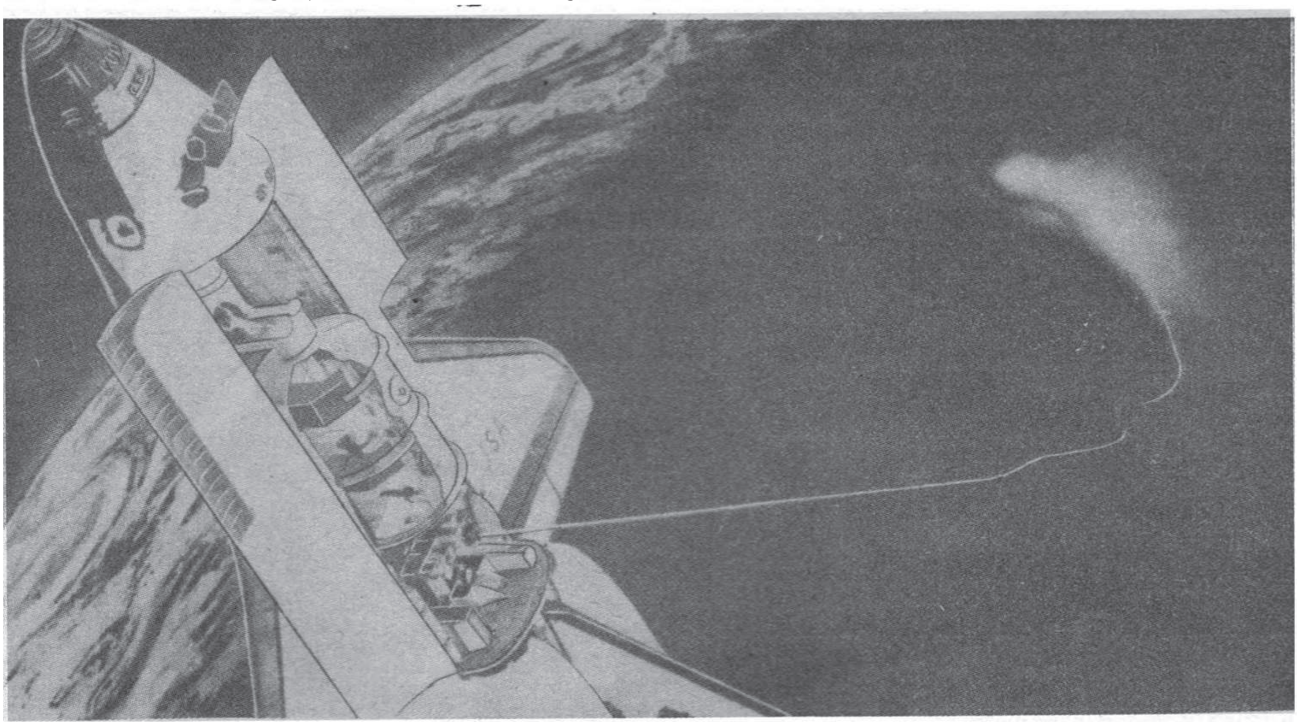
The Satellites

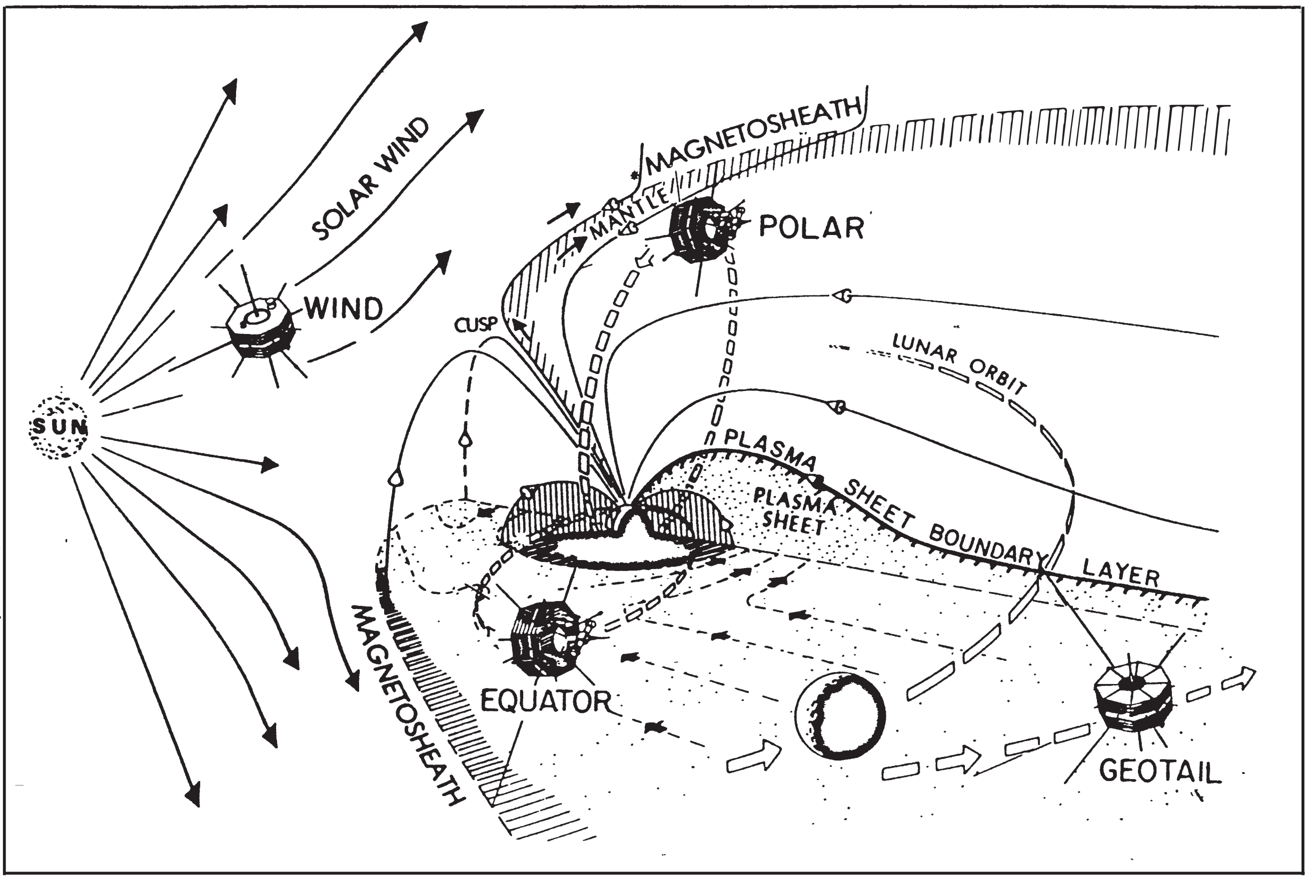
Four satellites are required in order to monitor the plasma source and storage regions simultaneously. The primary sources of plasma in geospace are the solar wind (a continual flow of material from the Sun) and the ionosphere (a region in the upper atmosphere). Primary storage regions are the tail of the magnetosphere (the region of magnetic fields surrounding the Earth) and the electric currents that surround our planet. To cover these four regions the four satellites are:

Wind will monitor the solar wind upstream from Earth at a distance of 6-250 Earth radii.

Polar will measure plasma flows from the ionosphere and flows into high latitude regions from space. It will be in a polar orbit of 6 by 250 Earth radii to provide good views

Scientists can now direct charged particles into the Earth's magnetic field lines to study their behaviour. *NASA*



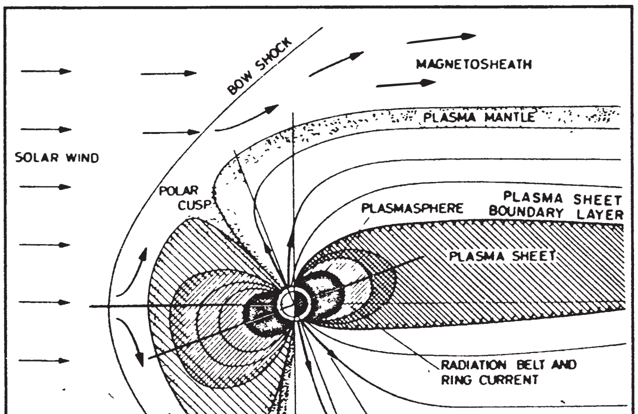


Geospace regions.

of the aurorae. Images of the aurorae from the X-ray to visible bands will be recorded every minute, so the data transmission rate for this spacecraft (42 kbps) will be much higher than for the others.

Equator will monitor the ring current that surrounds the Earth and acts as an energy and particle storage region. 'Equator' will be in an equatorial orbit of 2 by 12 Earth radii.

Geotail will orbit from a lunar flyby back to a distance of a few Earth radii to monitor energy and particle storage mechanisms in the geomagnetic tail. This craft will be built by ISAS whereas the others will be constructed by NASA with some European instruments.



All of these satellites will be launched from the Shuttle using Payload Assist Modules to move them into their required orbits. Basically, the satellites will be similar, weighing between 600 and 900 kg and using spin stabilisation at 10 to 20 rpm. Some 100 to 300 W of power from solar arrays will be consumed; data will be stored on tape recorders and played back through the telemetry system. Instruments will monitor magnetic fields, electric fields, plasma waves, plasma composition and energetic particle velocities.

A tentative schedule has already been put forward. Wind will be launched in 1989 to supplement measurements made by ESA's Ulysses solar polar mission. Polar will be launched in 1990, followed by Equator and Geotail in 1991.

In addition to these satellite observations at key points in geospace, complementary ground-based observations will be made, concentrating on the mechanisms of upper atmospheric heating by electric currents. Radar, magnetometer and photometer sites will be used around the world. 'Darn' will use a network of radar facilities in the northern latitudes to detect back-scattered radio waves from the ionosphere to reveal details on the structure. 'Mainstep' will study the ionosphere from Halley Station in Antarctica. 'Canopus' will study the aurorae and ionosphere from sites throughout northern Canada.

Numerous orbital geometry configurations will be employed. For example, the Wind satellite will fly in two different types of orbits. One involves a double lunar swingby where the spacecraft passes by the Moon on the way out to a distance of 200 Earth radii. The other is the 'L1 halo' which it will orbit the L1 libration point. At this position in space, 240 Earth radii away, a satellite can maintain its position with respect to the Earth with negligible fuel consumption.

SPACE RADAR FOR REMOTE SENSING

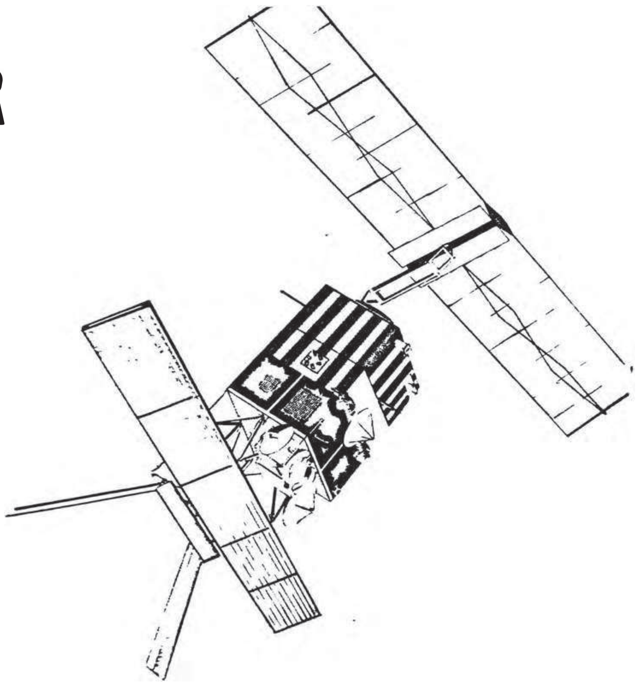


Fig. 2. The ERS-1 spacecraft; carrying a Synthetic Aperture Radar (SAR), a Microwave Wind Scatterometer and a Radar Altimeter.

By Dr. Harry Joyce*

A number of radar remote sensing instruments have been flown in low Earth orbit with considerable success. With interest in these all-weather high-resolution remote sensing systems increasing within the space and remote sensing communities, there are plans for a number of future radar remote sensing missions.

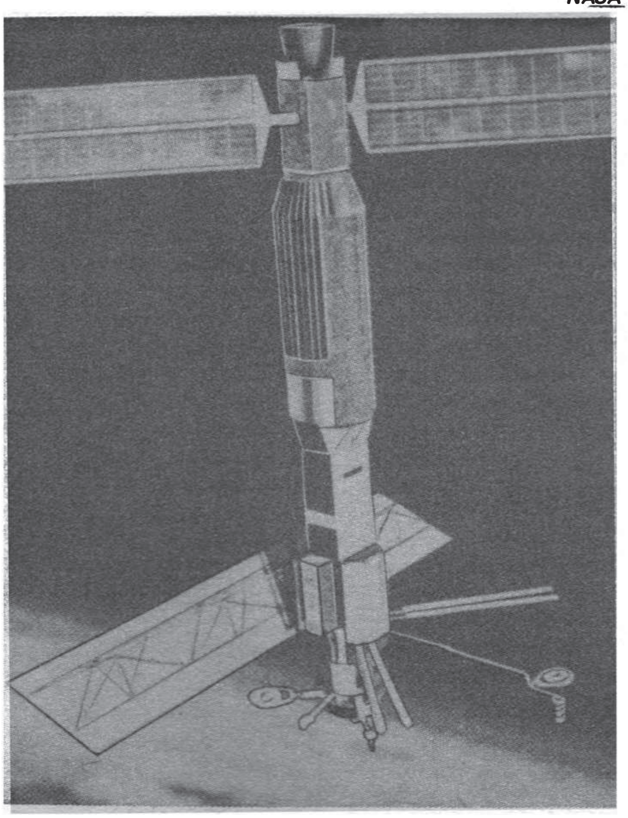
Introduction

Radar instruments observing the Earth from space can carry out a number of valuable remote sensing measurements over land and sea, including high-resolution altimetry, sea surface wind field and surface wave measurement, and high resolution radar imaging of land, sea and icefield regions. Because of their ability to make high resolution observations under virtually all weather conditions, radar systems complement optical, infra-red and passive microwave sensors to provide an 'all-round' remote sensing capability.

The history of spaceborne radar systems effectively began in 1974 when Skylab astronauts first used experimental microwave sensors to gather ocean surface data. The instruments included a Microwave Radar Scatterometer for ocean surface observations and a low-resolution Radar Altimeter.

The GEOS-3 satellite carried a high-resolution microwave radar altimeter and demonstrated the potential for radar altimetry for sea-state and surface level measurements.

Fig. 1. The Seasat experimental oceanographic research satellite. *NASA*



The successful NASA Seasat of 1978 carried a full complement of microwave sensors dedicated to ocean remote sensing research, including a scatterometer for ocean wind field measurements, an altimeter and an Imaging Synthetic Aperture Radar (SAR). The resulting data, examples of which are included here as illustrations, stimulated a great deal of interest in remote sensing circles and has clearly demonstrated the value of radar remote sensing instruments on space platforms.

Particular attention is drawn to two major remote sensing missions: the successful, though short-lived, Seasat experimental oceanographic spacecraft, shown in Fig. 1, and the European Space Agency's ERS-1 remote sensing satellite (Fig. 2), scheduled for launch in 1989 [1,2].

Spaceborne Radar Instruments

State-of-the-art radar instruments for space remote sensing applications fall into three broad classes *viz* the Radar Altimeter, Syntheic Aperture Radar and the Microwave Wind Scatterometer.

The Radar Altimeter

The radar altimeter measures its height above the surface of the Earth by timing the delay between the transmission of a radar pulse and the reception of the reflected echo [3]. This measurement, in principle very simple, can be made with great precision and can produce a great deal of information about the topography of the target area.

Modern radar altimeters enhance their altitude resolution by using 'pulse encoding,' or pulse chirping. By encoding each portion of the transmitted pulse with its own characteristic signature, the radar altimeter can use a long-duration pulse (typically 20 microseconds) to give a good signal-to-noise ratio while simultaneously achieving a very fine time resolution and thus a high resolution in altitude.

The high accuracies allow some very rewarding global observations to be made. As well as the obvious precise

* Manager, ERS-1 Systems Group, Marconi Space Systems, Portsmouth, England.

measurement of the geoid (the Earth's shape), sea surface levels can be plotted, showing wave patterns and allowing ocean currents to be deduced - matters of great interest to oceanographers and meteorologists. As an example, Fig. 3 shows the results of a Seasat radar altimeter survey of the oceanic western hemisphere. By making a number of precise sea level measurements over each area and combining the resulting data, the on-ground data processor has built up a picture that shows not only evidence of extensive ocean currents but also sea floor topography. This latter observation is possible since gravity causes sea bed irregularities to result in corresponding irregularities in the sea surface height above them. The sea surface height varies by 2-3 m for every kilometre change in sea-bed depth.

Altimeter data can also be used for plotting ice coverage in polar regions, including the deduction of ice thickness from the 'spreading' of the returned echo.

To achieve very high measurement accuracies, a number of sources of error must be tackled. The most serious are those associated with uncertainties in the precise position of the spacecraft at the time of measurement. However, using a combination of orbit modelling, periodic position location and precise altitude calibration (ERS 1 will employ a laser reflector mounted on it) these errors can be largely eliminated. There is room for improvement and efforts are under way to produce enhanced performance.

Synthetic Aperture Radar (SAR)

The Synthetic Aperture Radar employs sophisticated resolution-enhancing techniques to produce high quality images. SAR is one of the most fundamental performance enhancing techniques developed in the field of radar [4]. First conceived during the 1940's, it improves the spatial resolution of a moving radar system parallel to the direction of motion.

The ground resolution is a function of the antenna size: a space radar with a useful resolution would require an impracticably large antenna if SAR were not used. For example, a typical remote sensing mission operating in low orbit (i.e. at round 750 km) could achieve the 30 m resolution required for the ERS-1 imaging radar with a real aperture antenna more than 4 km long.

Aperture Synthesis takes a number of independent 'looks' at the same area as the spacecraft moves over it. The data are then summed by processing algorithms to produce a final image. In this way the satellite's motion synthesises a large antenna from the much smaller real one. The antenna can be quite modestly-sized but the data processor must work much harder - a classical hardware/software tradeoff. The technique allows ERS-1 to achieve a 30 m resolution with an antenna only 10 m long [5,6].

Spaceborne SARs also use the pulse coding technique, described earlier for the radar altimeter, to give a fine range resolution in the direction parallel to the radar beam.

An example of a SAR image obtained using these techniques is given in Fig. 4, which shows a Seasat image of the Chesapeake Bay Bridge area in Maryland, USA. The bridge itself is clearly evident in this 25 m resolution radar picture, as are long-wavelength surface waves in the bay.

The SAR imaging principle has a wide range of remote sensing applications including sea wave mapping, icefield plotting, pollution monitoring and ship tracking, as well as a host of land applications including geological surveying and crop monitoring.

The ERS-1 SAR uses the large 10 m antenna at the top of the spacecraft (Fig. 2) to transmit and receive, at a carrier frequency of 5.3 GHz. The transmit pulse length is 37.1 microseconds and the mean DC power requirement is approximately 1300 W.

Fig. 3. Seasat radar altimeter image of the Atlantic area showing sea-bed topography.

The Microwave Wind Scatterometer

The Wind Scatterometer is designed to measure the speed and direction of ocean surface winds. This cannot be done directly but by measuring the strength of the radar signal reflected from the sea surface from a number of different look angles are used the nature of the small wind-induced waves on the surface can be deduced. A complex mathematical model within the on-ground data processor takes these values of reflected energy and derives the wind velocity [1,5].

A stretch of water subjected to windy conditions shows just how dependent the surface roughness is on the wind and how this affects the surface reflectivity to visible light. The same effect pertains at radar frequencies and empirical models have been derived relating wind velocity to radar reflectivity from measurements with tower-mounted and airborne radars over the sea. Many useful wind field products have been obtained from Seasat Scatterometer data.

An impression of the wind field product required from the ERS-1 Scatterometer is shown in Fig. 5. A single wind velocity value is computed for each node on a 50 km grid within a 500 km wide swath along the ocean surface. In the final product vector arrows representing wind direction can also be numerically or colour-coded to give wind velocity information.

In order to resolve ambiguities in the wind direction data satisfactorily it has been found necessary to take independent measurements of the reflectivity at each sea surface point from a least three different directions. Hence the ERS-1 scatterometer system will have three indepen-

dent antennae (Fig. 2) with different pointing directions. ERS will be oriented so that all three scatterometer antennae, as well as the much larger SAR antenna, point Earthwards. One antenna, known as the Mid antenna, will point directly broadside to the direction of flight while two others will point independently at 45° to the velocity vector. AS ERS moves over the target area, the reflectivity at each point on the sea surface will thus be measured in turn by the three independent radar beams. Each of the three scatterometer channels will use a single antenna for both transmission of radar pulses and the reception of their echoes from the surface. The three resulting reflectivity values from each point within the target will be relayed to the on-ground data processor for conversion into a wind map similar to that shown in Fig. 5.

Radar Remote Sensing Missions

As well as the Skylab, GEOS and Seasat missions already mentioned, two Shuttle flights have carried successful Synthetic Aperture Radar remote sensing experiments and Japan is planning to use an Earth-resources SAR in 1988. Europe's ERS-1 Ocean Remote Sensing Satellite should begin operations in 1989.

The Canadian Government's Radarsat, currently scheduled for launch in 1990, will be an ERS-1 type mission including an altimeter, an SAR and a Wind Scatterometer. A major objective will be the monitoring of ice fields off northern Canada and elsewhere.

NASA's Topex satellite, due for launch in 1988, will carry a precision radar altimeter for Earth-surface topography surveying. Also of considerable interest is the US Navy's N-ROSS mission, which will include a Microwave Scatterometer for meteorological and oceanographic remote sensing.

The European Space Agency has plans for follow-on missions from ERS-1. ERS-2 will probably have ocean remote sensing objectives similar to those of its predecessor, while ERS-3 might well be a land-oriented remote sensing mission with a strong Synthetic Apeture Radar content.

In addition, there are a number of other possible applications of radar remote sensors in the pipeline, including NASA's Free-Flying Radar Experiment (Firex) and Space Station Imaging Radar (Spirex).

Future Development

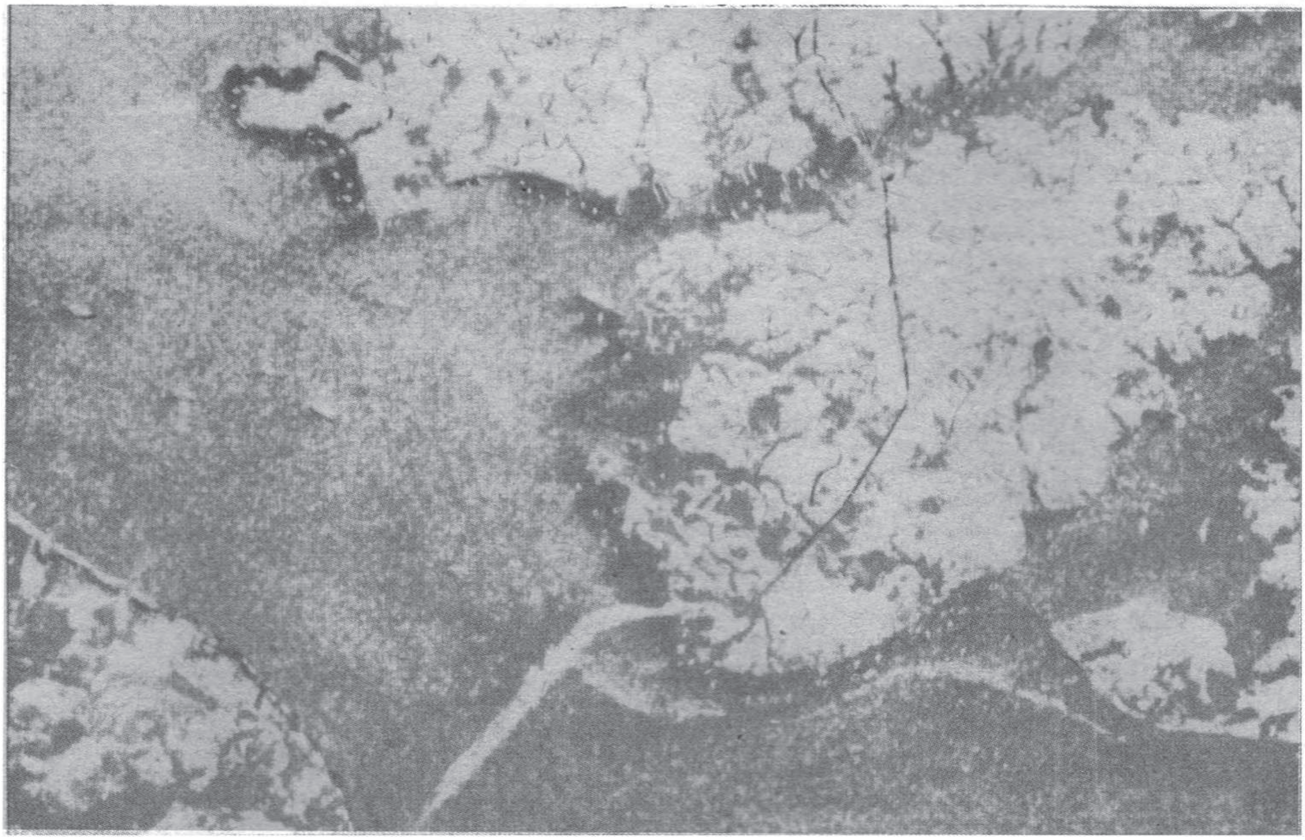
Remote sensing has produced valuable data, particularly over ocean areas, and the potential for these state-of-the-art instruments is enormous. Development efforts during the coming decade will centre largely on two areas that now present significant, though by no means insurmountable, constraints.

Owing to system constraints, mainly instrument power, mass and data output rate, the ERS-1 Synthetic Aperture Radar is usable over only about 10% of each 100 minute orbit. Although the Radar Altimeter and Scatterometer are both usable over large portions of each orbit, the widths of their coverage areas, or 'swaths,' will have to be greatly increased to meet the needs of meteorologists and others in the future. In addition to the actual ground coverage, the use of multispectral instruments will also increase. A number of important features of the radar echoes received, especially from land targets, vary significantly with the precise radar frequency used and also with the polarisation mode. Future sensors will use a number of different frequencies and polarisations to maximise the information content of received data.

A number of promising technological developments currently receiving attention are each expected to make contributions to the alleviation of mass, power, data rate and other constraints.

Mass reductions will be achieved by constructing

Fig. 4. A Seasat SAR image of the Chesapeake Bay Bridge Area. The spatial resolution is about 25 m.



antennae of carbon fibre materials instead of aluminium alloys, using lighter constructions for improved-efficiency amplifier tubes and, ultimately, by the use of semiconductor high-power amplification devices. The development of higher reliability components might, in some cases, reduce the requirement to provide fully-redundant equipment. On-board instrument controllers using microprocessor technology, as specified for ERS-1, will become universally applied. Improvements in high power amplifier efficiency, (typically 35-40% in high power systems at present), will bring significant mass benefits in conductors, power conditioners and amplification devices. New, lighter radio frequency devices will also yield some mass reductions.

Contributions to reduced instrument on-board power requirements will come mainly from increased high-power amplifier efficiency, improvements in component noise figures and associated performance improvements, allowing reductions in required transmit power. Another important power-saving area is in more selective sensor operation. An example would be a Scatterometer switching to a reduced performance mode over large expanses of ocean for which the wind velocity is fairly constant. Transmitters might be blanked out over target areas known to be of lesser interest, so conserving power. For the SAR there is also the possibility of operating at reduced transmission power over regions for which full performance is not required.

As mentioned earlier, there is the need to improve data communication with the ground. Since a satellite in low orbit can remain in contact with each ground station for a maximum of only about 15 minutes, clearly either a large number of stations are required - a very costly solution - or some other means of handling the generated data must be found. On-board storage of data (currently on high-density tape recorders) for oportunistic transmission to ground, and satellite data relay sytems are possible solutions. Present storage techniques cannot accommodate the very large data sets generated by SAR systems but a relay system could allow transmission to the ground *via* a communications satellite in geostationary orbit.

Data reduction procedures, similar to those used in digital TV broadcast systems, are also very promising for data handling. On-board data processing algorithms act to decide on the 'uniqueness' of each piece of data. If a significant period of largely unvarying data is detected then the total data set required to be transmitted can be reduced using some code defining the set length. Other criteria for data reduction, including auto-selection of image quality requirements, can also be implemented.

The second broad area in which significant improvements will be required is in the processing of the gathered data to derive the image products required by the user. In Radar Altimeter terms this means a detailed spatial map of land or sea surface height above some specified datum, such as that in Fig. 3, and other derived products. For the Scatterometer, wind field maps of required ocean area are necessary and, for the SAR, precision images or pictures of chosen target areas.

With current technological capabilities almost all image processing is done on the ground. The required complex error-correcting and compensating algorithms, the image-derivation algorithms and the sheer volume of data generated, particularly for SAR systems, dictate processing times that limit the usefulness in applications requiring near real-time data. For example, meteorologists would like a complete wind and wave map of the world's oceans renewed every six hours. To achieve this, increases in computing power and more efficient data processing algorithms will be required. Such on-ground data processing capabilities should be available within a few years.

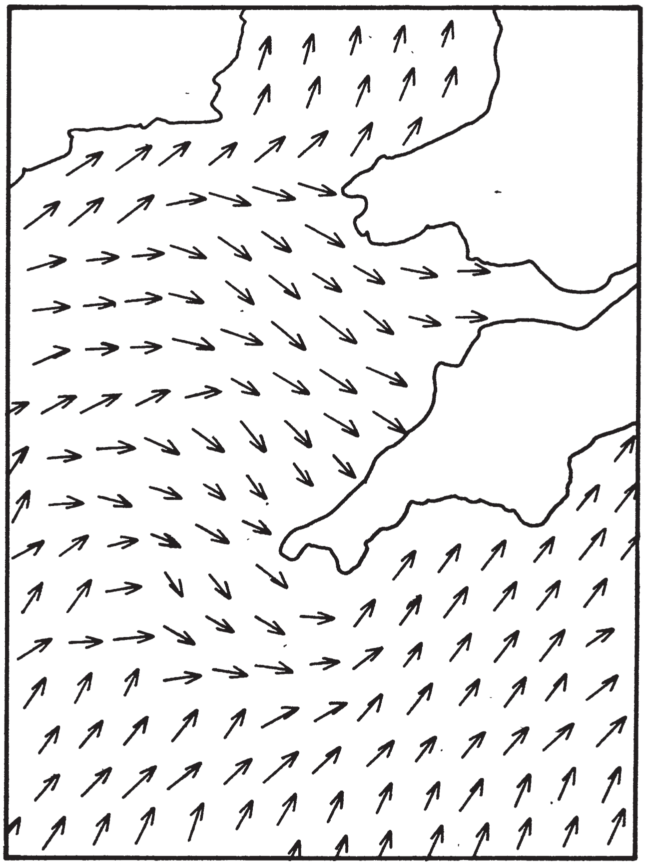


Fig. 5. A simulated windfield product from the ERS-1 Wind Scatterometer; derived wind vectors from each node on a 50 km grid.

There will also be a gradual shift of data processing from the ground to the satellite itself whereby final or near-final image products will be generated before transmission to ground. The benefits here will be profound. The amount of data for transmission will be reduced but, more importantly, the complexity (re cost) of the on-ground processor will be greatly reduced. The received data will be suitable for users with limited financial and technical resources. Since developing countries stand to benefit considerably from remote sensing, real benefits can be foreseen here.

Spaceborne radar instruments are a powerful tool in remote sensing applications. The potential for their application for the benefit of Mankind is enormous and we can expect to see many exciting developments within the near future.

REFERENCES

1. A.R. Hibbs and W.S. Wilson, 'Satellites Map the Oceans,' *IEEE Spectum,* October 1983, pp.46-53.
2. P.R.C. Gillet, 'ERS-1: An Ice and Ocean Monotoring Mission,' *JBIS,* **3**, pp.387-393 (1983).
3. M.I. Skolnik, 'Introduction to Radar Systems,' McGraw-Hill 1980, 2nd edition.
4. S.R. Brooks, 'Synthetic, Aperture Radar,' an Introduction to Spaceborne Systems, *Marconi Review,* **11**, 213, pp.88-104 (1979).
5. H. Joyce and R.P. Cox, 'Active Microwave Instrumentation for Europe's First Remote Sensing Satellite,' *Electronics and Power,* February 1984, pp.141-145.
6. F.G. Sawyer, R.P. Cox and H. Joyce, 'ERS Synthetic Aperture Radar Design,' International Geoscience and Remote Sensing Symposium, IGARSS '84, Strasbourg, France, August 1984.

APRIL 1986

Spaceflight

The International Magazine of Space and Astronautics

CONTENTS

Editorial Office:
27/29 South Lambeth Road,
London, SW8 1SZ, England.
Tel: 01-735 3160.

Spaceflight is published 10 times a year and is distributed internationally by post to:

1. Members of the British Interplanetary Society, free of charge.
2. Individual purchasers for personal use at £2.00 (US$4.00) per issue (1986).
3. Libraries at an annual institutional subscription (1986) of £30.00 (US$50.00) inclusive of issues of *Space Education* Magazine.

For Air Mail delivery to non-European countries add £1.50 (US$2.50) per issue. All subscription payments should be sent to the Editorial Office (address above). Details of application for membership of the British Interplanetary Society are available from the Executive Secretary, the British Interplanetary Society at the same address.

* * *

Editorial and advertising enquiries should be addressed to the Editorial office. Responsibility for security and all other clearances necessary for publication rests with the author. Manuscripts are accepted only on condition that all such matters have been completed. Opinions in authored articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

* * *

Published by the British Interplanetary Society Ltd., (No. 402498) Registered Office: 27/29 South Lambeth Road, London SW8 1SZ, England.

Vol. 28 No. 4 April 1986

Front Cover: An artist's impression of Hotol flying into orbit. The British Aerospace/Rolls Royce horizontal takeoff spaceplane relies on a revolutionary new propulsion system. If development proceeds as planned the spaceplane could be in operation before the end of the century. A full report on Hotol plans begins on page 147 and is followed by a special review of British space activities. *BAe*

Spaceflight
The International Magazine of Space and Astronautics

HOTOL – TOWARDS THE 21st CENTURY

The announcement that the Hotol "Proof of Concept" Study is underway at last on joint government/industry funding must be welcome to those who look for a new UK attitude to Space. The amounts involved are small, and it has taken a perhaps characteristically long time for the announcement to be made, but the decision shows a positive readiness to look to new ventures in Space for the future. If this is to set the "style" for the new British National Space Centre, it should be applauded.

Let us be clear just what has been agreed. The Hotol Proof of Concept Study is to establish whether the breakthrough in launch vehicle concepts claimed for Hotol by British Aerospace and Rolls Royce is real, and more importantly how immediately that breakthrough can be translated into a usable launch vehicle. Establishing the timescale is a key. It is not a commitment by the UK to develop such a vehicle, still less to develop it as an independent project separate from its partners in Europe. The UK now has perhaps 18 months to achieve the objectives of Proving the Concept before it must go to its partners as a proposer of a joint project.

In the mean time the French will continue to press Europe down the route of Ariane 5 and Hermes as the launch vehicle for the late 1990's.

It is probably the French who will have to make the most difficult decision regarding Hotol. The UK has made it clear that, at the end of the Proof of Concept Study, it will share the results with its European partners. If those results are positive then the French will have to decide whether to abandon Ariane 5 and Hermes, or more realistically just Hermes, and embrace Hotol. This is why the potential timescale is important. It establishes whether Hotol is a replacement, or a successor to Ariane 5/Hermes. But the decision is not simply whether Europe should take a conservative or high risk route on its future launch vehicle.

Across the Atlantic, while the UK finds a few million pounds for studies, the USAF is putting hundreds of millions into a new vehicle concept called the Trans-Atmospheric Vehicle or TAV for short. The immediate need is military, but if it can be made to work the TAV will have a direct impact on civil launch costs. It will bring launch costs per kilogramme down by an order of magnitude.

If Hotol can work, then TAV can work. And if TAV flies, NASA will have, by the end of the Century, the low cost launch the Shuttle should have been but was not. The UK is pursuing a number of lines which look remarkably similar to Hotol – and against that competition, Ariane 5 and Hermes will make no in-roads whatsoever. Without a competitive launch vehicle, Europe could find itself not only out of the launch vehicle business, but out of commercial Space altogether.

That is the real challenge of Hotol – not whether Europe can afford to do it, but can it afford not to?

But if Europe does manage to take a deep breath and plunge in, the rewards could be much greater than simply remaining in the Space Business. Almost every aspect of the commercialisation of Space, with the exception of communications satellites, is today held back by the high cost of launches. To lower the costs by a factor of five or more would be an immense stimulus to growth in these other areas.

Finally, there is a converse to this subject. It may be that Hotol proves not to be the route to the 21st Century for Europe. In that case the UK must be prepared to support Ariane 5 and Hermes as actively as it would have expected France to support Hotol. In not joining directly with the US TAV studies, but showing a readiness in the first instance to share the Hotol findings with Europe, the UK has indicated its readiness to be a "good European". The next generation of launch vehicles and the European capability for man-in-space operations are too important for the UK to ignore or simply to fill a minor sub-contractor role supplying bolts and fittings. Hotol has shown that the UK is prepared to think innovatively in Space and to participate with Europe, and it must continue to participate at that level.

Viewpoint

Flying into the Future

by Clive Simpson

Development of a revolutionary new engine by Rolls Royce is the key to British plans for Hotol, the horizontal takeoff and landing vehicle, a project which could put Europe at the forefront of commercial operations in space by the turn of the century.

The dual-functioning engine being designed for Hotol represents a quantum leap forward in propulsion technology – it will be able to breath air from the atmosphere during initial stages of operation before switching to internal fuel supplies when external air becomes too rare.

In tandem with development of the Rolls Royce propulsion system, British Aerospace is studying the feasibility and design of the Hotol spaceplane. Initial studies should be complete by the second half of 1987 and will cost £3 million, half of which will come from the government-funded British National Space Centre (BNSC). The Hotol development programme includes 12 test flights and seven orbital test flights, which would begin in early 1996 and conclude with the start of commercial operations between 1998 and 2000.

British Aerospace first announed its ideas for Hotol in August 1984 and since then the concept has become a subject of increasing interest both within Europe and in the United States.

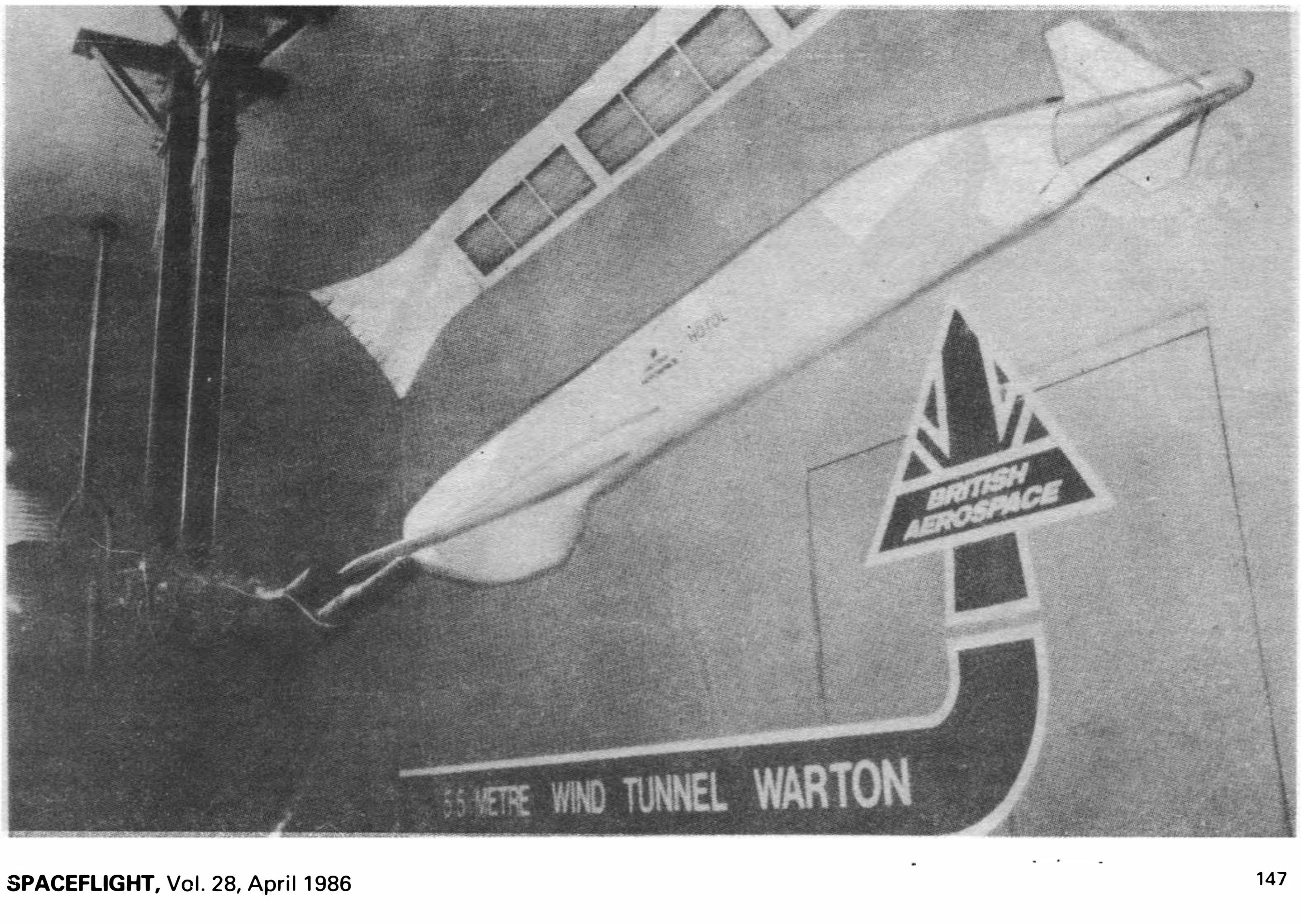
The goal of Hotol is to achieve launch costs to low Earth orbit of about one-fifth those of current launch systems such as the Shuttle for a typical seven tonne payload. The ability of Hotol to recover satellites and dock with Europe's Columbus and the American Space Station will also be investigated during the proof-of-concept studies.

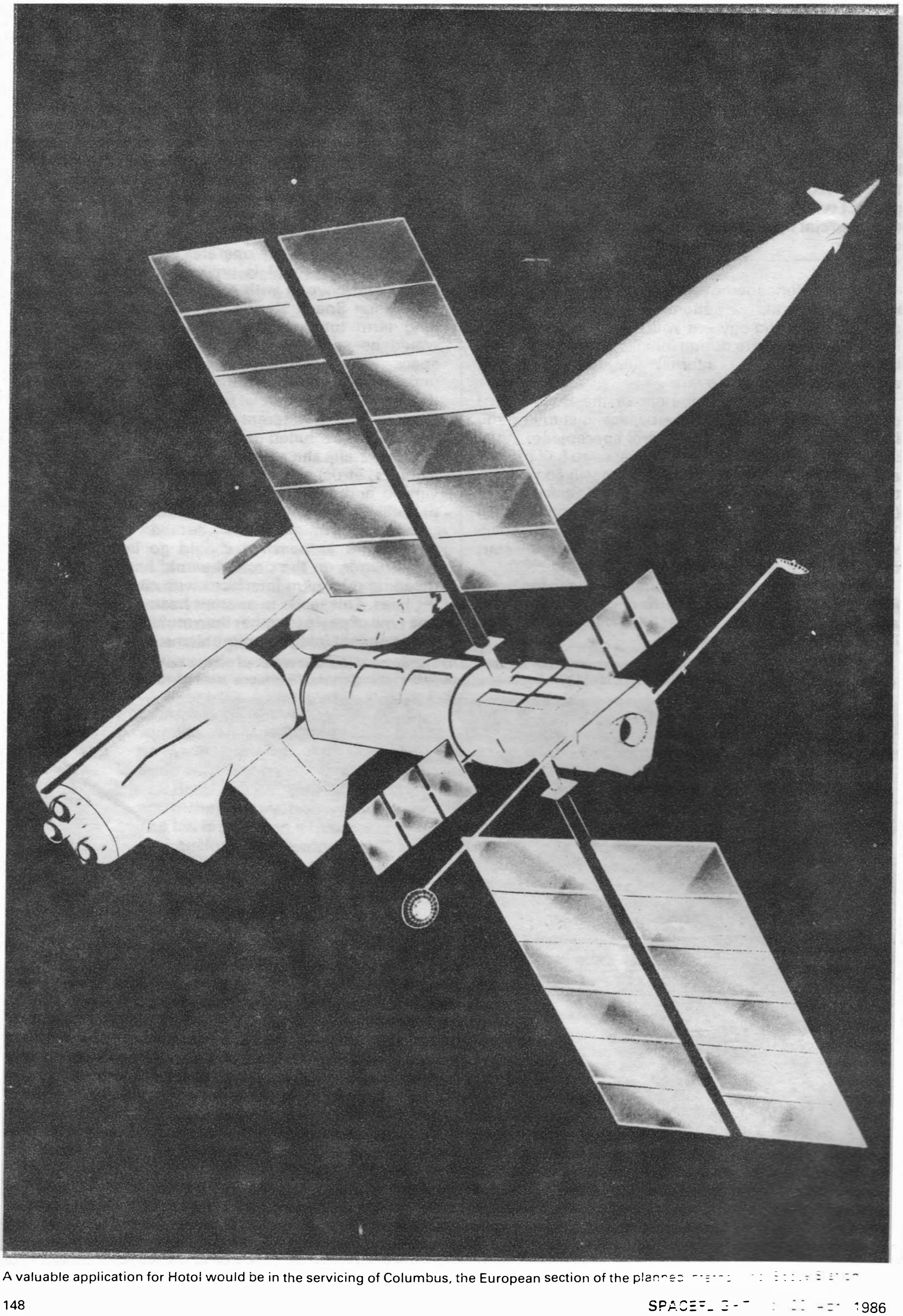
The spaceplane concept stems from the belief that a launcher system which operates by throwing away its components in flight is unlikely to compete in the 1990's and beyond with a greatly improved, second generation Space Shuttle. So, convinced that in the long term total reliance on expendable launchers would be seriously detrimental to Europe's future space interests, British Aerospace engineers undertook far-reaching studies to identify and design the optimum commercial launch vehicle.

More than 30 different configurations were studied and it was concluded that for a recoverable, reusable launcher all the expensive hardware (engines, avionics, structure) should be collected into a single vehicle and anything that left the ground – except propellants and payload – should return again.

In addition engineers agreed that as little deadweight as possible should go into space and turnarounds on the ground would have to be rapid, meaning minimum interfaces with cargo and ground facilities. This leads to another basic design criteria – one type of payload rather than multiple payloads with the attendant integration problems.

A scale model of Hotol in the 5.5 metre wind tunnel at BAe Warton. Recent design changes have removed the two vertical fins at the rear and altered the small foreplanes which are now spaced 120 degrees apart around the vehicle's nose. Wind tunnel testing began in early February.





A valuable application for Hotol would be in the servicing of Columbus, the European section of the planned [illegible]

As a result the concept of the "ideal" launcher emerged – a single-stage-to-orbit vehicle able to operate from a simple launch area with an airliner-type frequency.

Hotol is based on a remarkable new propulsion technique which allows the use of atmospheric oxygen to reduce the onboard propellant mass and permits the use of wings to optimise the initial flight trajectory after takeoff from a standard runway.

This combination makes the long sought after, single-stage-to-orbit launcher a practical proposition. The propulsive and aerodynamic characteristics result in a vehicle that is fully recoverable and totally and quickly reusable with minimum refurbishment, preparation and expense.

Hotol's hybrid engine would use atmospheric oxygen and onboard liquid hydrogen to accelerate the vehicle to high speed in the lower, denser layers of the atmosphere and then transfer at a suitable altitude and speed to pure rocket propulsion using the liquid hydrogen and onboard liquid oxygen.

The vehicle emerging from the design boards is basically part aircraft and part spacecraft with a brand new propulsion system. It is roughly the same size as Concorde and the two also have in common the same take-off mass and payload.

Most of the forward fuselage of Hotol is occupied by a large pressurised liquid hydrogen fuel tank while at the rear is a liquid oxygen tank for flight outside the atmosphere where air breathing is not possible.

The payload bay – of Shuttle diameter – is between the two tanks and the overall layout ensures minimum movement of the centre of gravity during flight.

Engines would be conventionally mounted at the rear and protection for re-entry heating would be concentrated largely underneath the fuselage and wing. Thermal protection would be by carbon carbon material on areas of high temperature and a titanium/ Rene 41 nickel sandwich on low temperature areas. The skin panels (measuring one foot by three feet) would not require periodic replacement as do the Space Shuttle tiles.

Take off mass would be some five times the landing value, as opposed to about twice on a conventional aircraft, giving rise to a great disparity between takeoff and landing undercarriage requirements. Therefore, Hotol would be launched from a laser-guided trolley with a lightweight undercarriage provided for landing. This arrangement would meet one of the criteria of ensuring as little deadweight as possible being carried into orbit.

A take-off speed of 290 knots would be achieved with an acceleration of 0.56g and a run of 2300 m. Vertical acceleration at lift-off would be 1.15g with a climb altitude of about 24 degreees.

Hotol would go supersonic after two minutes, clearing commercial air lanes (12,000 m) after 4.5 minutes and reaching a speed of Mach 5 after just nine minutes. The fuel burned up at this point would be about 18 per cent of take off mass, compared to a typical value of 50 per cent for a vertical takeoff vehicle.

At the nine minute point external air-breathing would no longer be possible and a ballistic trajectory on main engine would begin. Orbital velocity would be achieved at 90 km, the main engine would then cut off and Hotol coast to an operating altitude of around 300 km.

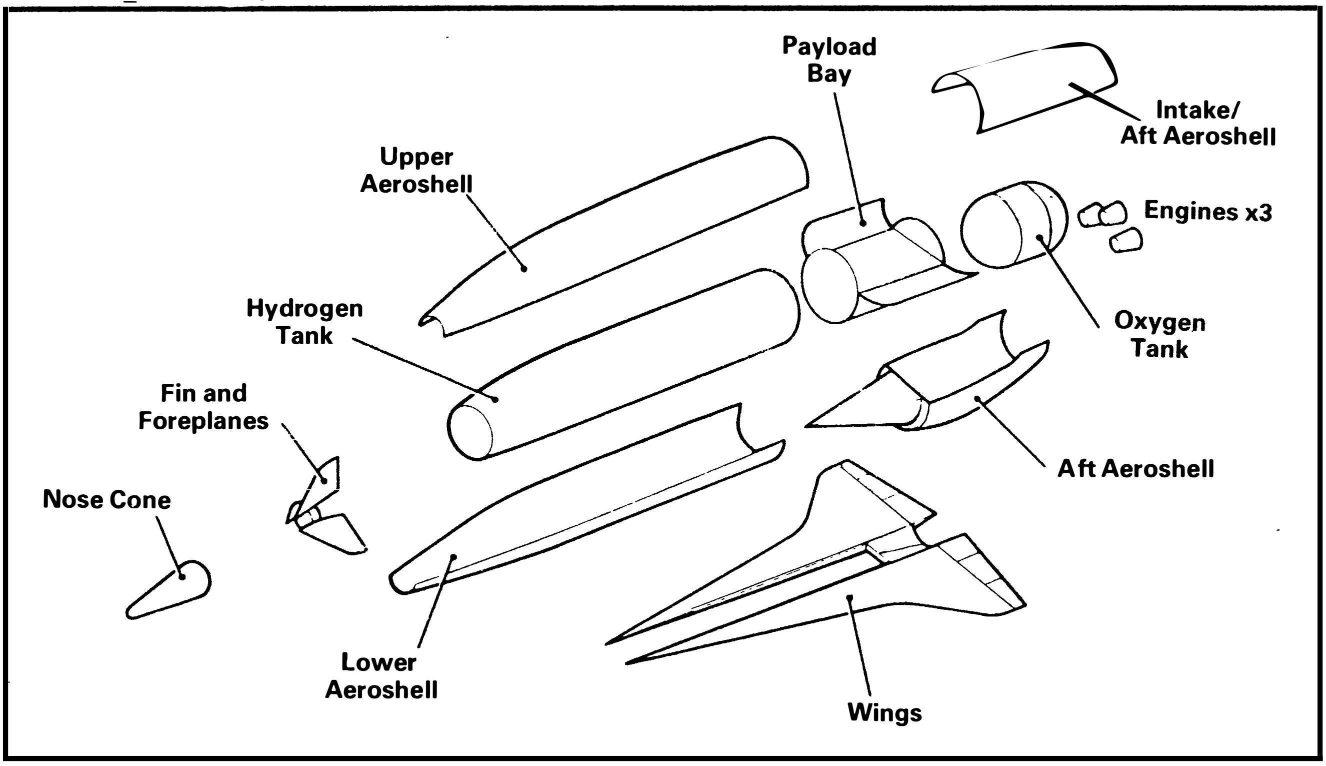
Maximum mission duration would be 50 hours with position and altitude changes achieved by an orbital manoeuvring system.

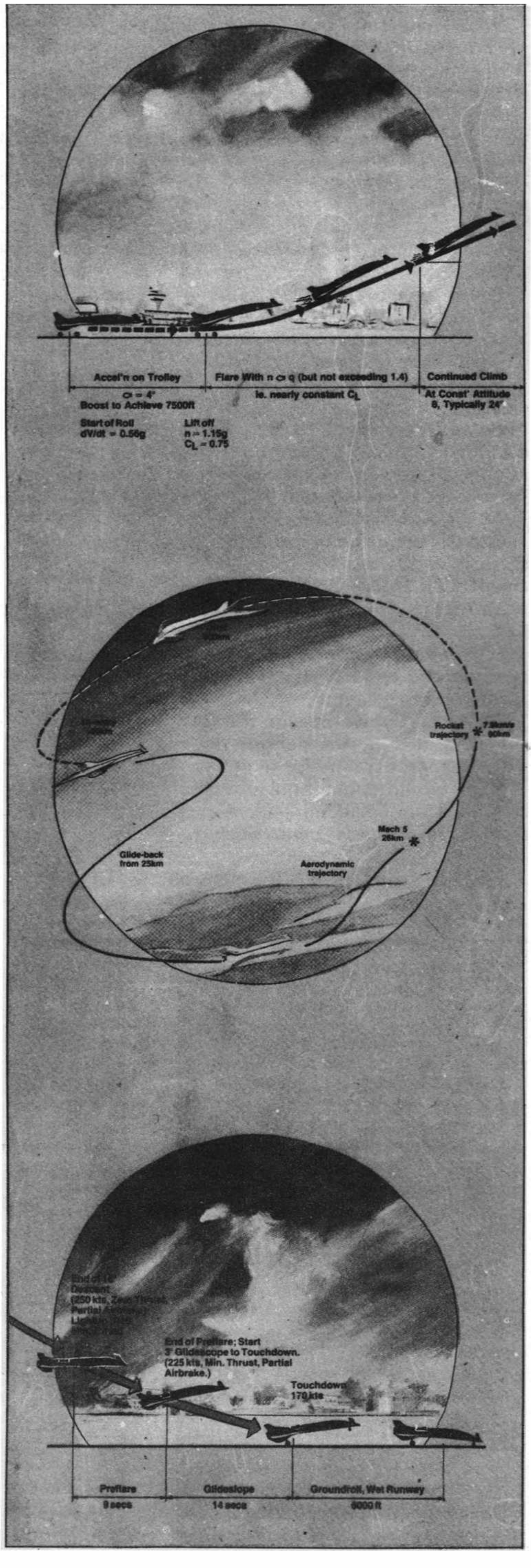
At the end of its mission the OMS would slow the vehicle and bring the perigee down to about 70 km altitude in preparation for re-entry.

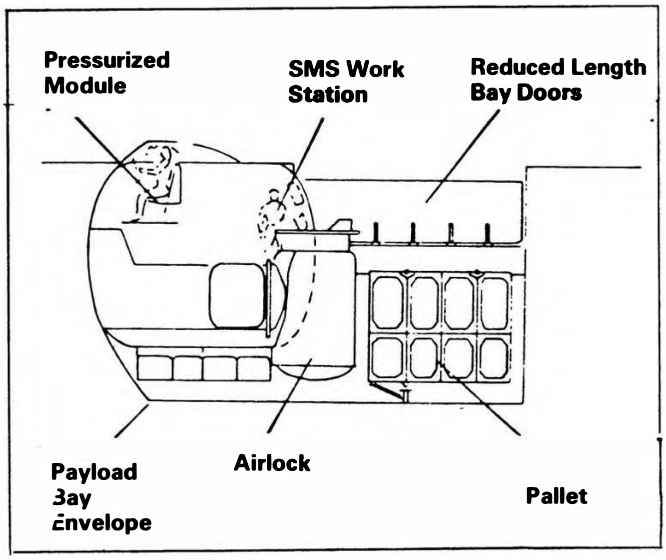
Hotol would re-enter the atmosphere at a very high incidence (about 80 degrees), reducing as speed falls – a hypersonic glide commencing at about 25 km altitude.

Because of its large wing area and low mass the

Breakdown of Hotol structure







vehicle would behave much less like a projectile than the Shuttle. Re-entry temperatures would therefore be lower and a high-temperature metal alloy skin would suffice for protection of the under surface, all meaning simpler construction and maintenance.

The high hypersonic lift-to-drag ratio of Hotol during re-entry (more than twice that of the Shuttle) gives a high cross range capability, sufficient for a landing in Europe from an equitorial orbit.

Final approach and landing techniques would be similar to the Shuttle but gentler: approach angle 16 degrees, touchdown speed 170 knots and the roll on a wet runway 1800 m.

For simplicity and economy the first operational Hotol will be remotely piloted by means of artificial intelligence and robotics systems. However, from the very outset provision will be made for manned operation.

The strategy on manned operations is only to include men when they are needed for orbital or Space Station operations. A manned module would be situated in the cargo bay and those onboard would play no role in launch and landing activities.

Manned missions would only take place after the unmanned version of Hotrol was fully proved and it is likely that one vehicle from a fleet of about six would be dedicated solely for manned missions.

Designers confidently predict that Hotol will reduce costs to low Earth orbit by a factor of five and, even with current perigee stages, will halve the cost of putting a satellite into geosynchronous orbit.

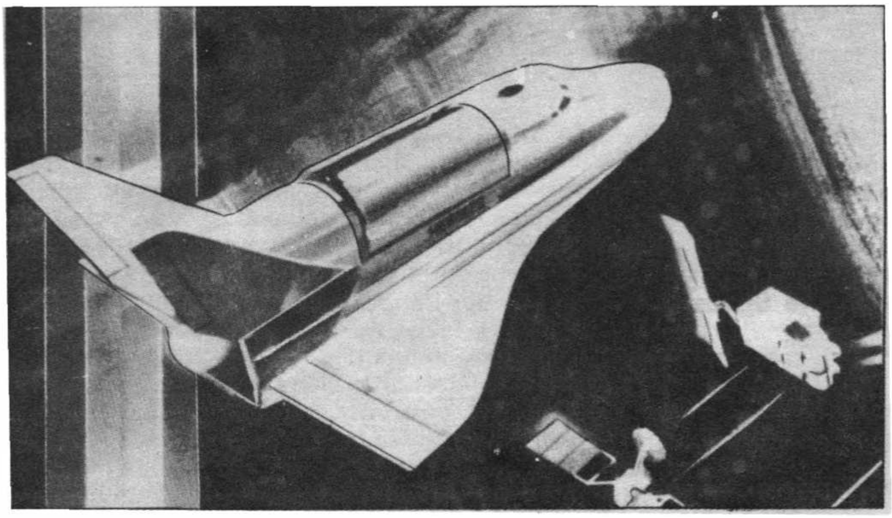
Such economy of operation, coupled with quick reaction and a rapid turnaround time (less than seven days) would enable Hotol to compete realistically for about 75 per cent of the commercial launch market from the year 2000 onwards.

In addition Hotol technology is forward looking with ample potential for development beyond the cheap and effective spacecraft launcher which it is presently planned to be.

Indeed, a one hour passenger flight from Europe to Australia is a distinct possibility around the year 2010 and it takes little imagination to identify other important uses for such a remarkable flying machine. A second generation Hotol could also have the potential for world-wide sales. Development costs for Hotol are currently estimated at £4,000 million.

HOTOL VERSUS HERMES

Britain and France could be shaping up for a head on clash within the European Space Agency (ESA) in trying to win formal approval of their respective Hotol and Hermes programmes.



Towards the end of 1985 the French Space Agency, CNES appointed Aerospatiale and Dassault-Breguet as prime contractors for development of its manned mini-shuttle project, Hermes.

The craft, to be launched atop the as yet to be developed Ariane 5 heavy lift launch vehicle, would essentially be used as a service vehicle for space stations, transporting crew and cargo.

Typical missions might include the assembly of space structures and scientific and applications experiments, as well as in-orbit repairs, maintenance and refurbishment of satellites.

Development of Ariane 5, an expendable booster, was approved during ESA's Ministerial Council meeting in January 1985 and the current design is based around a configuration known as Ariane 5P which has a central body with an HM60 large crygenic engine with two side-mounted strap-on solid boosters.

France is keen for Hermes to be adopted as an ESA programme and a project briefing was given by CNES to member states before the January 1985 ministerial meeting.

Reaction was lukewarm and the project was merely "noted with interest" (together with Britain's Hotol plans) in resolutions passed by the ESA members as a last minute compromise. CNES has stated that it will look for bi-lateral agreements with other European nations as an alternative route. Belgium, Sweden and Italy have already shown interest.

The proposed mini-shuttle is 15.5 m long with a delta wing and small vertical stabilisers at the wing tips. The wingspan is 11 m. A large vertical stabiliser would be located behind the payload bay, which has a volume of 35 cubic metres, above the orbital manoeuvring engines.

Propulsion into orbit after Hermes separates from its launcher will be provided by two 20 kN engines mounted in the rear fuselage. Dissipation of excess heat from the systems onboard, crew and variable solar heating once in orbit would be provided by radiators on the inner side of the payload bay doors, similar to the system used by the American Space Shuttle.

In contrast to the development of Hermes, the United Kingdom is actively pursuing an alternative and altogether more innovative path to the future.

The joint British Aerospace/Rolls Royce Hotol project is for an advanced horizontal takeoff and landing spaceplane which would be completely reusable and capable of operating in manned or unmanned modes.

Hotol relies on revolutionary new propulsion technology being developed secretly in Britain and so far unmatched by the rest of the world.

The choice facing ESA between Hermes and Hotol is not easy: Hermes is based on existing technology, Hotol is at the cutting edge; and if Europe chooses Hermes will it loose out when the United States develops its own transatmospheric spaceplane as a replacement for the Space Shuttle? It is doubtful whether both Hermes and Hotol would be financed simultaneously by ESA member countries.

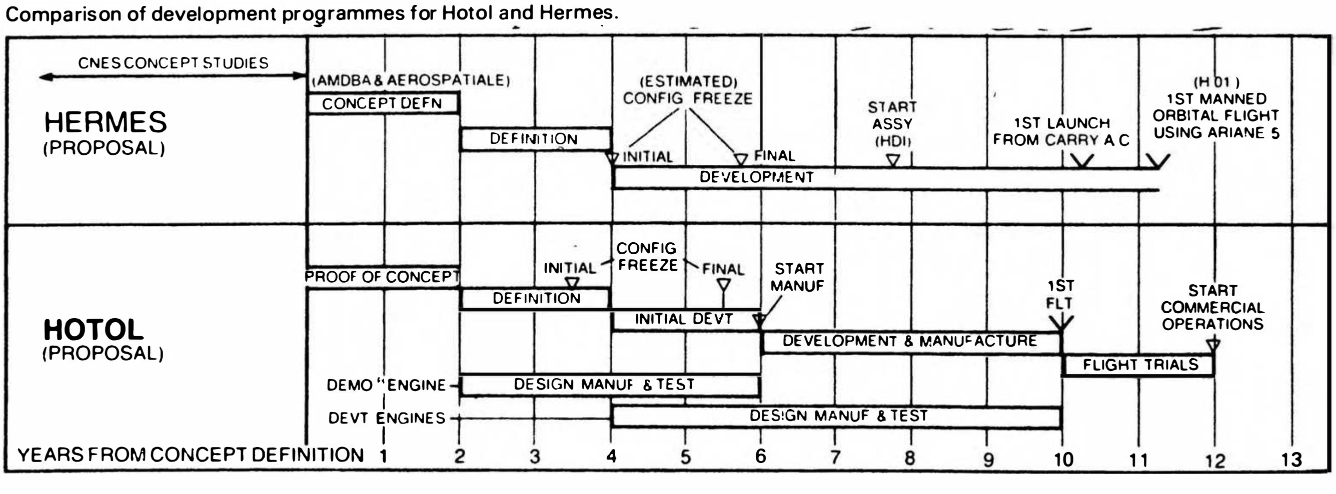
Peter Conchie, business development manager for British Aerospace Space and Communications Division, describes it as "a very difficult situation".

"We don't have any solution to the problem of how we get the Hotol programme endorsed by ESA. It is only a matter of time before the US catches up – all we can do is give Europe a little grace.

"Traditionally France spends most money within Europe on launch vehicles. It is not easy to see how they can embrace Hotol," he says.

The estimated cost of development for Hermes through to the initial two test flights is £1,050 million, More than £9 million has been provided for Hermes studies in the period 1985/6 with a further £15 million allocated for 1987. This compares with the £3 million recently announced for proof-of-concept studies lasting into the second half of 1987 for the Hotol spaceplane.

Comparison of development programmes for Hotol and Hermes.



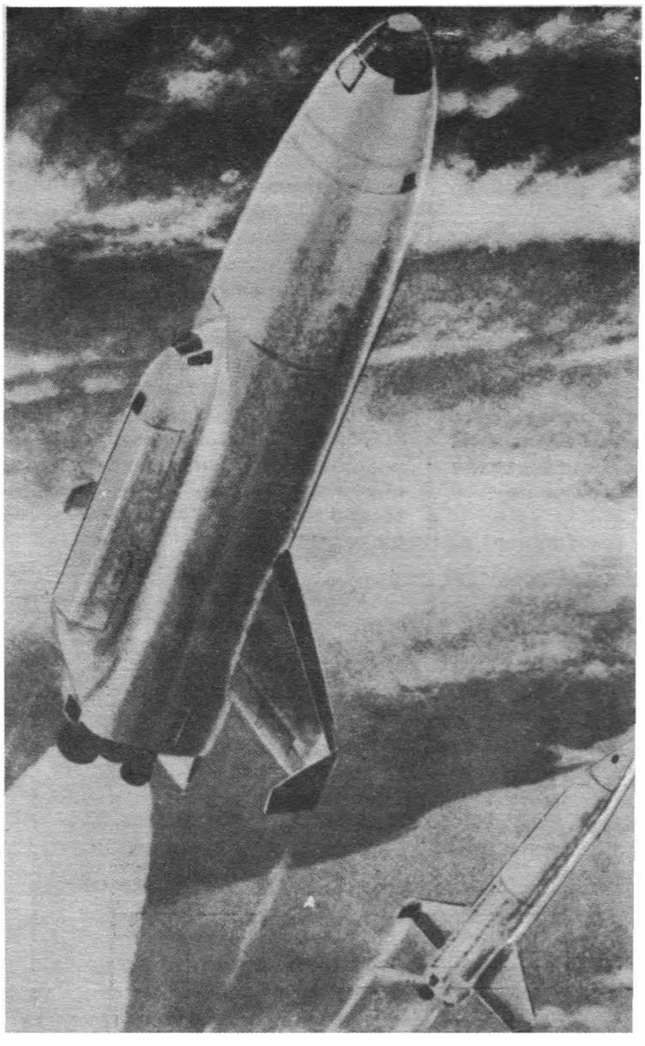
US Pumps Cash Into Spaceplane Development

by Stephen Byford

As British engineers begin work on the next phase of the design of Hotol (see previous pages), their American colleagues will also be engaged in the initial planning of a one-stage horizontal-take-off spaceplane capable of accelerating directly into orbit. It is hoped that this project will evolve into a possible successor to the Space Shuttle.

In the aftermath of the tragic Space Shuttle accident, President Reagan has stressed his continuing support for the American manned space programme, including the Shuttle and the proposed permanently occupied Space Station. In addition to these existing commitments, he has announced the development of a transatmospheric vehicle which, after taking off from Washington like an ordinary aircraft, could "accelerate up to 25 times the speed of sound, attain low Earth orbit or fly to Tokyo within two hours". Reagan calls this new craft the "Orient Express" of the next century.

A vertical takeoff two-stage concept for a spaceplane developed at NASA Langley in 1984. The orbiter would use both hydrocarbon and hydrogen engines, and the crew and payload would be located above the propellant tank.



The President has thus emphasised the civilian applications of the proposed spaceplane. The Orient Express could be described, however, as a spin-off from a project born of military motives. A joint programme for the design of an experimental aerospaceplane is already planned, Defence Advanced Projects Research Agency (DAPRA), Strategic Defense Initiative Organisation (SDIO) and NASA. Only a fifth of the funding for the project will come from NASA – the rest will be supplied by the Defence Department. Separate hypersonic research efforts within these two organisations have already been brought together.

A major pressure for the development of a single-stage launcher comes from President Reagan's Strategic Defense Initiative (SDI). Such a system for defence against ballistic missiles would probably require a decrease by a factor of almost ten in the cost of putting a given payload into orbit before it could become economically viable. This can only be achieved by the development of a second-generation Space Shuttle.

The US administration also feels the need to match what it sees as the more responsive launch capability now posessed by the Soviet Union. They point out that the Soviet space effort is much more closely tied to military operations than is the case in the USA, and that the Soviets have a greater capability to produce boosters and rocket engines than all of the western allies put together. They are also currently developing a number of new launch vehicles.

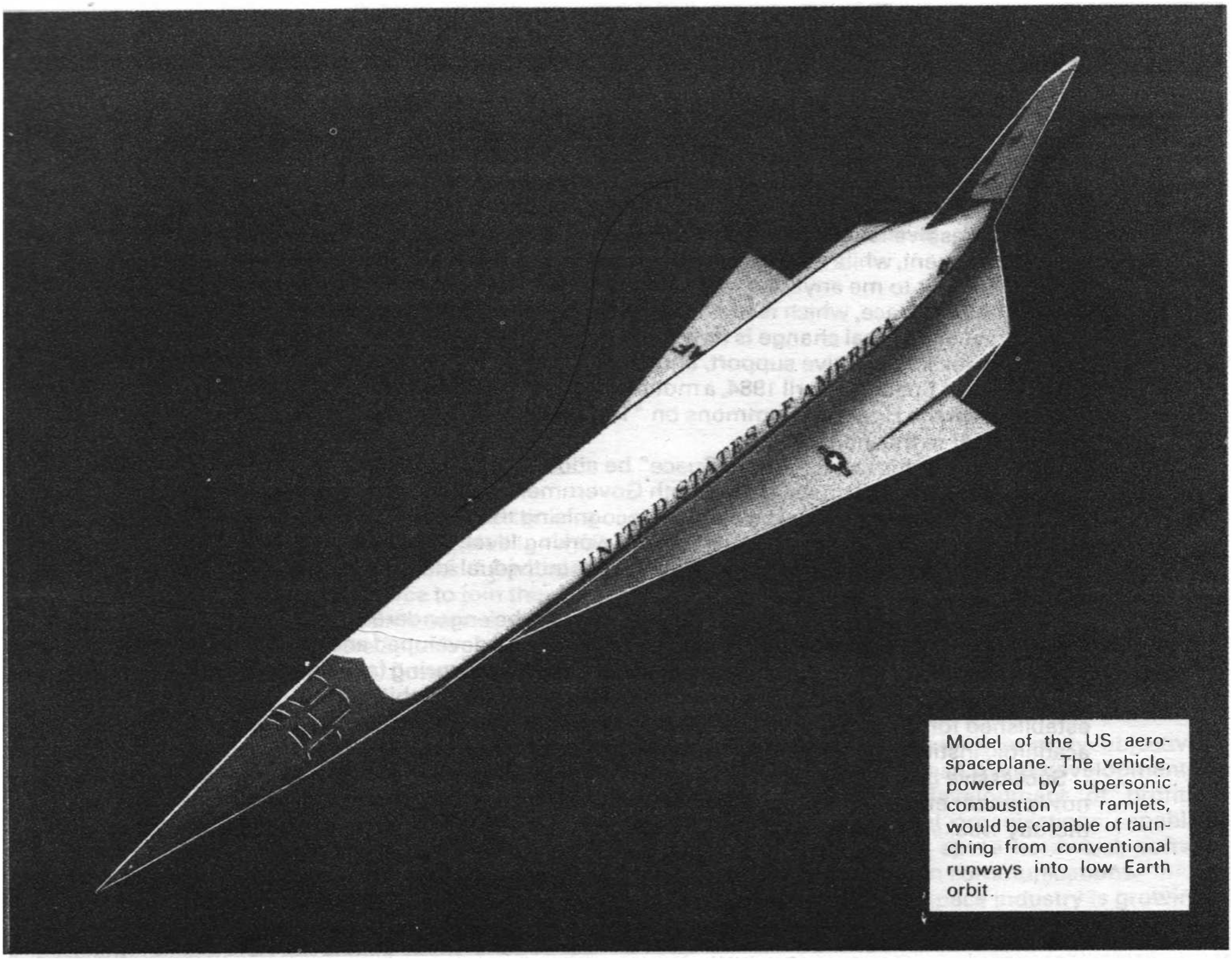
It is therefore feared that, during an international crisis, a combination of expendable launchers and the existing Space Shuttle would be unable to replenish military space systems quickly enough. This task could become vital, with intelligence gathering, early warning and global communication now becoming increasingly dependent on satellites.

The overall technological direction of the programme is the responsibilty of a joint office at the USAF Aero Propulsion Laboratory, Wright-Patterson Air Force Base, Ohio.

Despite the mainly military purpose of this project, however, commercial and scientific users will, no doubt, also benefit in the long term from the greater launch flexibility and lower costs involved in using the new craft.

Although the programme involves substantial risks, it is widely believed within the aerospace community that it may now be technically feasible. Several developments have contributed to this belief, including breakthroughs in propulsion research, advanced materials, cooling techniques, solid oxide fuel cells, giving greatly improved thrust-to-weight ratios, and the design and simulation facilities provided by the latest large computers.

The propulsion question will prove to be central if the new vehicle is indeed to be capable of taking off horizontally, from a runway, without the need for the



Model of the US aerospaceplane. The vehicle, powered by supersonic combustion ramjets, would be capable of launching from conventional runways into low Earth orbit.

large support crews currently required for Shuttle launches. The current concept is a hydrogen-powered aircraft that would, for much of its ascent, consume atmospheric oxygen instead of carrying large tankfuls of liquid oxygen. It would fly at speeds of Mach 12-25. Work at the USAF Aero Propulsion Laboratory suggests that such a vehicle could be operational by the end of the century.

During its air-breathing phase, the craft would most probably be propelled by supersonic combustion ramjets (scramjets). These are essentially modified remjets, which rely on the aircraft's motion to compress the gases, since they lack turbines. However, scramjets will only operate efficiently at hypersonic speeds (above Mach 5). Consequently the Americans are alleged to be interested in the secret of Hotol's engines which, according to Rolls Royce, also work well at lower speeds.

The latest ideas for a US spaceplane have evolved from the initial exploratory efforts of NASA and DARPA in the period from 1982 to 1985. This year sees the beginning of the next phase of the programme, which will consist of the additional technological development required for an experimental flight vehicle, and the construction and testing of engine modules up to the current maximum wind tunnel speed of Mach 8. This phase will be directed by DARPA.

The aerospaceplane programme was allocated $30 million in last year's budget; this will now rise to $500 million over the next three fiscal years. The implications of the idea will be studied in the context of global flight, civil transport and as a long-range air defence interceptor. This constitutes the most extensive American air/space research programme since the North American Rockwell X-15 project of the late 1950s.

UNITED KINGDOM

THE WIND OF CHANGE

For many years, the BIS voiced the message that 'Money spent on Space is spent here on Earth ... on new know-how, new training and new high-tech industries', but it almost always fell upon deaf ears.

Political resolve for a broad-based and long-term commitment to Space has long been noticeably absent, while other countries forged ahead. From MP's on both sides of the House one heard 'Don't put to me anything that I cannot offer to the electorate', or 'My postbag is full of everything but Space, which is of no interest whatsoever to the public'.

The wind of political change is now blowing, even in Britain. MP's *do* receive letters about Space, expressing positive support, and there are MP's who realise and advocate the national importance of Space. In April 1984, a motion, proposed by six MP's and sponsored by 51 others, was tabled in the House of Commons on "The Space Industry", calling for greater Government commitment to the industry.

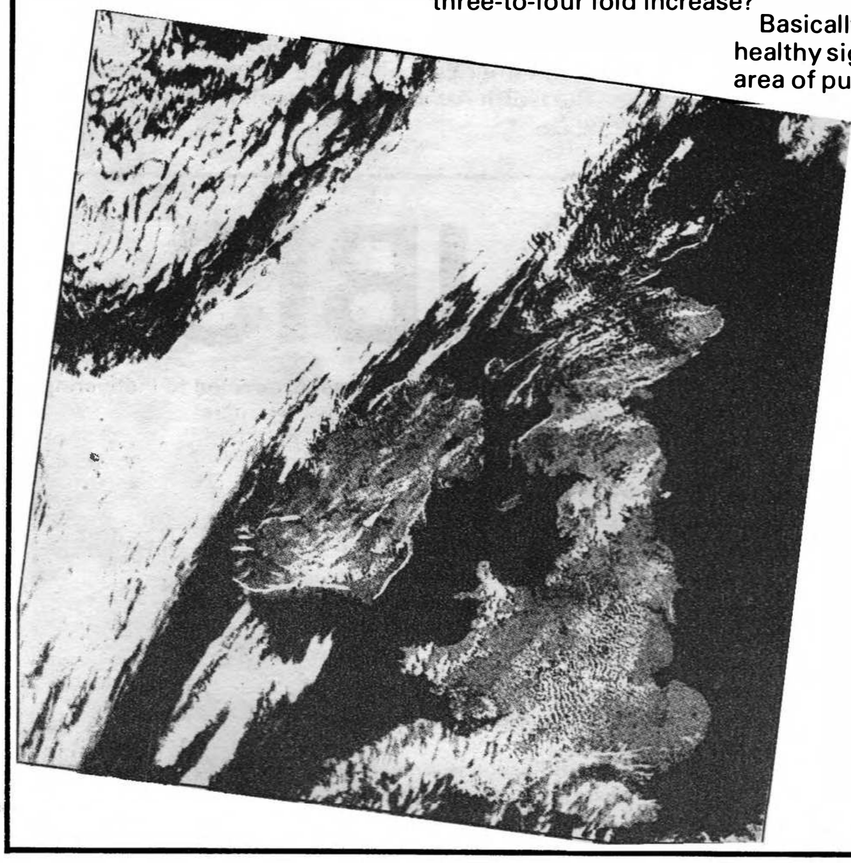
What should this call for "more Space" be about? First, more resources and a better use of resources are needed on the part of both Government and Industry. Also a routine and progressive attitude to Space is needed, recognising that Space provides many spin-offs by raising levels of interest and competence at working level, by opening up new areas of employment and by bringing financial returns to individual industrial companies and the nation as a whole.

The vision needed is a broad one. Interest needs to be engendered at school level and carried on into universities where innovative capabilities can be developed and new know-how created. Training programmes together with technical and manufacturing facilities need to be supported in a co-ordinated and sensible way to meet Space-orientated objectives. UK Centres need to be established for the commercial development of space which are closely associated with academic institutions actively researching in the same specialist fields.

Successive governments have failed to realise the country's true Space potential and even now present effort and expenditure are well below the nation's potential level of achievement thereby weakening its position internationally.

The Space Station programme is here to stay and needs to be exploited to the full in all its aspects, including an astronaut programme of selection and training to be initiated at an early date. The UK has been dragging its heels instead of moving boldly forward in many important areas.

Can the situation be remedied? Can we expect the UK Space Budget to equate to that of Germany or France within, say, the next five years with a three-to-four fold increase?



Basically, a change is already taking place. A healthy sign is that the change is underway in the area of public opinion.

Space is now commanding public interest and approval. The news media sense this and are treating the topic more respectfully, thus providing the informed and balanced presentation which the public need. Space in the UK is finding acceptance with the electorate. The Government has sensed the new situation and has established the British National Space Centre to co-ordinate the country's hitherto fragmented Space effort. The follow-on period is now all-important. Expenditure will need to be restructured and in certain directions substantially increased.

This special UK section highlights the present position of the UK in space. We gratefully acknowledge the assistance of Mr Geoffrey Pattie, Minister of State for Industry and Information Technology, Mr Roy Gibson, Director-General of the BNSC, and Mr Tom Mayer, Chairman of the UKISC, as contributors.

Space – Today's Challenge and Opportunity

by Geoffrey Pattie, MP

MP Geoffrey Pattie, UK Minister of State for Industry and Information Technology, Department of Trade and Industry, London, puts forward a British view on past, present and future developments in space.*

Geoffrey Pattie, UK Minister of State for Industry and Information Technology.

The space age is only a little over a quarter of a century old. When the first Sputnik satellite was launched, few then realised that mankind had been given the key to a whole new resource to join those of the land, sea and air. In this short time period, we have landed men on the Moon, explored portions of the two nearest planets (Mars and Venus), flown near Jupiter, Saturn and now Uranus, provided revolutionary new means of communication, built great new industries, brought remote sensing from space to the threshold of operational use and begun to plan how to achieve a permanent manned base in space. Most importantly, we have come to rely on space in a significant way because of its unique vantage point and special properties.

Britain's Space Heritage

British scientists and engineers were among the first to realise the potential of space and Britain's space industry was established in the early 1960's with the Ariel series of scientific satellites. Our first home-built satellite was Ariel III which, following its launch on an American Scout rocket, established our scientists among the leaders in the field of x-ray astronomy, a position they still hold today.

Our Defence Ministry was also quick to appreciate the potential of satellites for communication, setting up its first such links in 1966 – it was after all an Englishman, Arthur C. Clarke, who first pointed out the potential of the geosynchronous orbit to provide worldwide high quality communications – and we put the world's first military geosynchronous satellite, Skynet I, into service in 1969 and subsequently its British-built successor, Skynet II, which is today still providing useful capacity.

Thus we now find ourselves in Britain very creditable users of space systems – indeed perhaps the biggest user of space systems outside of North America in the OECD countries and therefore probably third in the world with a strong and active involvement in military, scientific, operational and commercial sectors.

In the civil field, we played a leading part in setting up the necessary international organisational structures and we are founder members of Intelsat and its European regional equivalent Eutelsat, of Inmarsat and Eumetsat and above all the European Space Agency.

**Adapted from an address at the Western European Union, Colloquay, Munich, September 1985.*

In Britain the Government's primary objective in supporting civil space research and development has been to promote the development of profitable industrial and commercial organisations capable of producing and exploiting space hardware, software and services, particularly in communications.

Employment in British space industry is growing at more than 10 per cent a year and the current order book is twice the size of annual turnover. This is quite a success story and Government has been undoubtedly achieving its main goal. Continuity of policy has been an important factor in this providing a stable climate for growth but the responsibility, and congratulations for its growth lie, quite rightly, with the industry itself.

The space business is a risky business and just as it has been impossible for the space industry to bear the burden of investment by itself, so it has been important for Britain to co-operate with the governments and industries of other countries in major space projects. The United States and Soviet Union have had the economic strength, political will and defence requirements to develop a fully comprehensive space capability. There is now a recognised third force in space – Europe. By collaborating through the European Space Agency, the 13 member states and one associate have between them developed a comprehensive capability. It is through ESA that the main British effort has been directed over the last ten years and now we can see that it has been remarkably successful with its scientific, meteorological, launcher and applications programmes.

It is ESA which has established Europe as a powerful force in space and made its industry second only to the US in the market place. A major virtue of ESA is that it is structured so that new space programmes can be started with a minimum of formality and with different mixes of contributions from the member states. The elements of each programme can be selected from the countries best able to produce them successfully and economically, whilst still having formal mechanisms

to ensure that each member state gets a fair share of interesting work in return for its financial contribution.

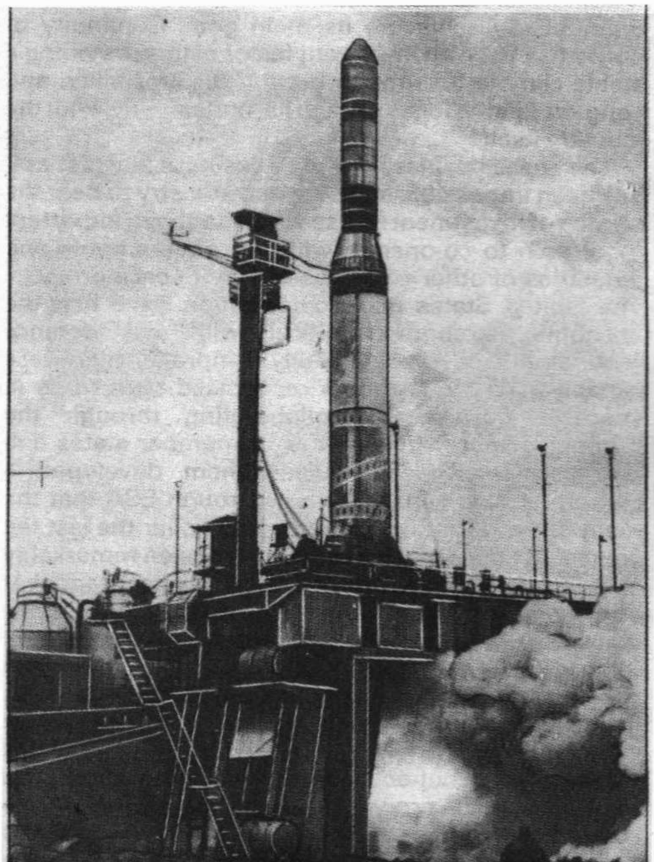
Our experience in space so far in Europe has shown that:

- Europe acting together in high technology can be a major force on a par with the super powers;
- Organisations need to be flexible, able to adapt to changing circumstances and manifestly fair for each of the partners;
- Genuine co-operation draws on the strengths of the participants. Thus so far in ESA, Britain has concentrated on telecommunications satellites, France on launchers and Germany on manned space facilities, all with notable success. These aspects will be brought together even more closely in the Columbus Space Station Programme.
- It can pay to be bold in creating new institutions –with ESA, Arianespace, Inmarsat and Eutelsat all excellent examples.

British Organisation for Space

A recurrent concern for Governments, because of the high costs of space research and development, is when, where and for how long should it be involved in funding space efforts? And what is the proper balance between public and private funding for space research and development? Even more directly – what incentives are needed to encourage the private sector to assume a larger role in developing and exploiting space technology?

The successful Blue Streak booster used here as the first stage of Europa after the British-built ballistic missile was cancelled as a military project.



In Britain the Government took the decision early in 1985 that there was a need to build on present arrangements for co-ordinating what Government did in space by establishing a British National Space Centre to improve the development of space technology in the United Kingdom and to co-ordinate policy more effectively.

In Britain, as elsewhere, a growing range of users of space services is spread across Government, academic institutions and all types of industry. As they have become more aware of the benefits offered to them by space, it has become more important to establish a single focus to which they can turn for advice and technical support. We hope they will seek to influence the programmes of the Centre by making their own financial and in-kind contributions. Our aim is to improve the use of public resources and I believe that one of the most effective ways in which we can be sure of achieving this is to invite industry to play a major role within the new Centre.

The establishment of a National Space Centre does not signal a new direction in our space policy in Britain. Rather it emphasises the Government's commitment to the development of space technology for industrial, scientific and defence purposes. Our aim is to ensure the best use of available technology and that national resources are not wasted through unnecessary duplication of effort. Uniquely, we will be seeking to run some civil and defence space efforts together. One gain that we look for from this is the easier transfer of the results of publicly funded research into the civilian economy. Our new agency will therefore be orientated towards serving a variety of national needs including some of those in defence and we see it providing a single focus for space research and development in support of Government and the private sector.

Gains we look for include better budgetary and programmatic co-ordination of national space research and development effort, and a better balance between technology "push" and user "pull". More positively we hope that the new Centre will permit the total space budget to be adjusted more readily to changing policy priorities and that it will facilitate the development of joint programmes in areas such as space infrastructure of interest to the entire space community in Britain. ESA will remain the cornerstone of our civil space activities.

The Pace of Progress

Turning from means of implementation to applications, we find today that Intelsat, now 20 years old, has over 100,000 satellite voice circuits installed, working into 650 Earth stations in 165 countries. At the time of Los Angeles Olympics, live TV was brought to over one billion viewers in 68 countries – something that only satellites could do but which we now take for granted.

Against this background it is hard to believe that there has been, and remains, a perennial problem of bringing about the new services that satellites can offer. A classic case of this pre-dates space, and goes back to the early day of aviation when the Australian Post Office is said to have dismissed as uncompetitive the communication possibilities of aircraft in favour of

camels!

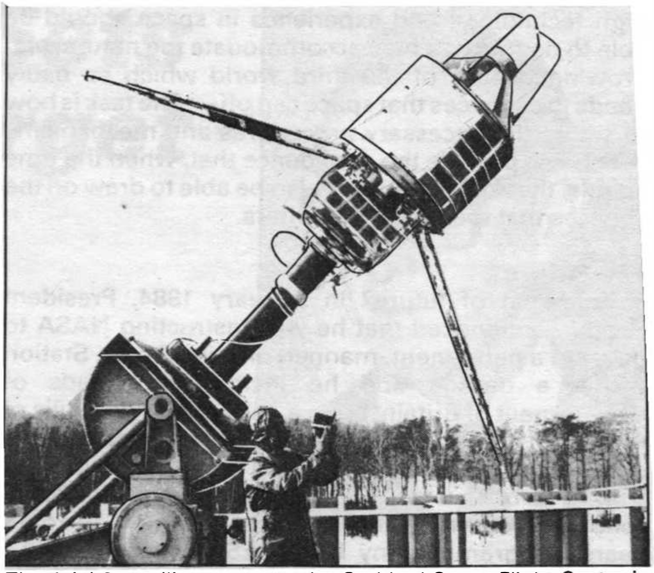
All too often we find prospective customers saying that they have grown and prospered without the new capabilities and the services that space has to offer. Examples abound of telecommunication authorities who, in the 1960's and indeed into the 70's, insisted that their existing technology of microwave links, undersea cables and so forth could adequately meet their needs, and who were all too ready to reject as insupportable the prospective costs of satellite services. And yet, this was in a field which had an organised user community and technology was being offered which was merely going to be a substitute for other technology. It is not surprising that we find yet more difficulty with other fields of space, such as remote sensing, where no one single user has a dominant role or need.

The problem of course is the classic error of failing to foresee how advances of technology can outmode habitual ground rules and ways of thinking and so alter the way in which routine everyday tasks are accomplished. We have to be alive to continuing advances in technological capability out-dating principles that had previously been thought to be fundamental. Whereas in the early days it seemed self-evident that the role of satellites was that of inter-continental communications, linking national telephone systems and using large dishes – like additional cable services in outer space rather than in the deep space of the oceans – we now see increasing use of the widespread coverage afforded by satellites to bring international television programmes via small individually-owned dishes straight to hotels and blocks of flats.

Satellites can also now provide a vital contribution to industrial infrastructure, with computer talking directly to computer via satellites in a deluge of digital bits as it organises the day-to-day working of an industrial conglomerate.

Up to now the world's satellite communications have been provided by legislated or de facto monopoly organisations, and complete liberalisation would be both highly contentious and, in my opinion, ill-advised. However, it seems likely that we will have to look carefully through the 1980's and 90's at the institutional arrangements of Intelsat and other bodies that we have established to organise services and share the cost of space facilities. These bodies have been extraordinarily valuable in developing effective and reliable satellite services, and the oldest of them, Intelsat, has shown the importance of a dynamic approach to its mandate and to the changing environment of telecommunications. But with satellite communications moving more and more from the macro to the micro level, we must make sure that reasonable opportunities are provided for the entrepreneurs in our society, without at the same time jeopardising the good facilities that we currently have.

Satellites are also, of course, causing some deep thought on the question of broadcasting policy. Previously, terrestrial technology has ensured that live television transmissions were effectively confined to national borders. But from a vantage point 36,000 km above the Earth's surface, satellites recognise no frontiers and, working into small dishes situated in the back gradens or on the roofs of dwelling houses, are



The Ariel 3 satellite on test at the Goddard Space Flight Center in America.

now bringing other cultures into the homes of millions in the shape of foreign TV programmes. The implications of this technological trend are far-reaching and need to be considered with great care.

Today, we find that Britain is the largest user of satellite capacity in Europe, with half a dozen UK-originated television channels being beamed into cable heads and hotels throughout Europe. In social terms, this represents a revolution of considerable political significance which, I am glad to say, has so far proceeded relatively painlessly. But the potential for objections to "cultural invasion" and possible pressure for encryption in order to control reception is self-evident. The conflict is one of freedom of speech and political unification as opposed to a natural desire on the part of all countries to preserve their cultural identity, and with its multiplicity of nations, each with its own distinct language and traditions, this is particularly relevant to Europe.

A further issue which we can be sure will not go away is the question of how to ensure that all countries gain free and equitable access to the natural but limited resources of the geostationary orbit and the radio frequency spectrum. This is a problem which relates not so much to satellite broadcasting as to satellite telecommunications. It is a matter of entirely understandable concern to many countries for whom a national telecommunications satellite is an ambition for the future that, by the time they are ready, the advanced countries may have occupied too much of the orbit and of the most desirable spectrum. To that end, many developing countries have set their sights on a rather rigid form of planning which would set aside a "slot" for each country. The difficulty is the waste involved in reserving parts of a valuable resource, unused, against a need which may be several-lifetimes distant in many cases.

The other side of the coin is represented by present users who have already built a growing business from operating satellites and who, looking for a reasonable degree of security of tenure, view with reluctance the idea that they may at some future date be asked to move aside to make room for a newcomer.

This is an area where the developed world with its

high technology and experience in space should be able to do much to help accommodate the natural and growing conern of the third world which so badly needs the services that space can offer. The task is how to set up the necessary procedures and mechanisms which will provide the confidence that, when the time comes, these countries will also be able to draw on the services that the Space Age offers.

The Future

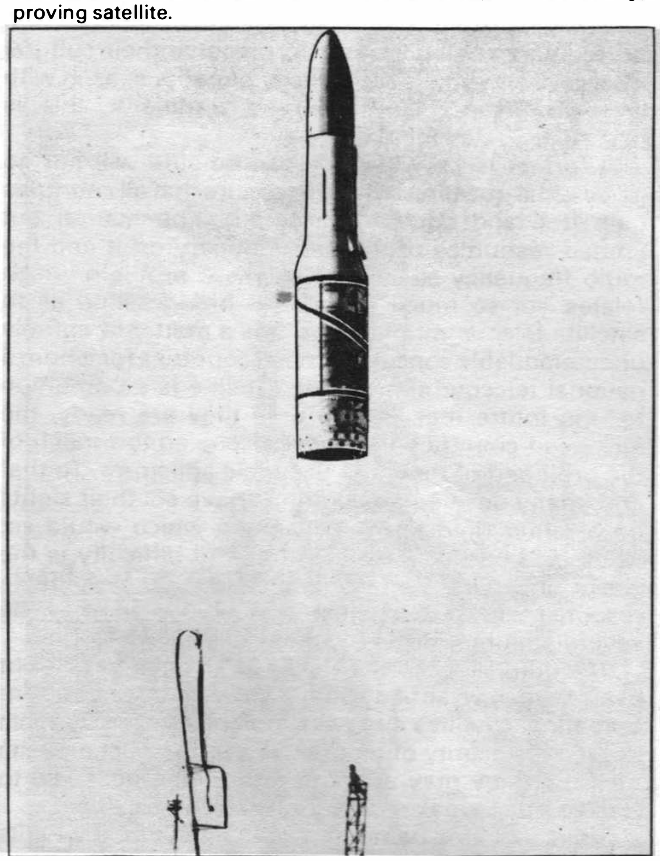
But what of future? In January 1984, President Reagan announced that he was instructing NASA to develop a permanent, manned orbiting Space Station within a decade and he invited the Heads of Government of Britain, France, the Federal Republic of Germany, Italy, Japan and Canada to participate in this project. Costs were expected to be in the region of $10bn. Subsequently at a special meeting in Rome called to determine the shape of our next 10 to 15 years' programme, my fellow ESA Ministers and I decided in principle to participate in this great co-operative endeavour, subject of course to satisfactory arrangements on costs, involvement and access being agreed.

The Space Station is a logical extension of the lessons and experiences of the last 25 years. The move towards more wide-spread and personalised services, the need for even greater reliability and the finite capacity of the orbital resource, all point to the need for larger, more closely-integrated space systems such as can only be achieved by man's intervention in orbit, and the Space Station is to be the first step on the road towards this objective.

But it is not only what the Space Station will technically enable that will be important. Equally important will be the effect that the Space Station will have in capturing the imagination of the young and encouraging them into the pursuit of high technology careers upon which the continued growth of the world as a whole depends. Success in this area too will be an important manifestation of the bonds between the Western democracies. But co-operation implies genuine partnership, and my fellow Ministers and I in Europe will be looking for an opportunity to play a meaningful and worthwhile role which is clear-cut and free-standing. For we are acutely aware that, although technically successful, Spacelab, our contribution to the Space Shuttle programme, has fallen somewhat short of real operational success, with operating costs and access arrangements making it relatively unattractive to the customers for whom it was intended. We do not want to make this kind of mistake again.

We now have a period of intensive work before us with the Space Station project in the definition stage which will detemine mission, design and cost details. In parallel with this, we shall be holding detailed Governmental discussions to clarify the important questions of technology transfer and terms of access which will be crucial to our joining the building and operational phases. All being well, I hope that we will be able to cement Western solidarity with a mutually-beneficial co-operative programme having an impact extending well into the 21st century and that we will be able to move forward together in 1987 with full development.

A British Black Arrow rocket being launched from Woomera in South Australia in October 1971 with the X-3 (Prospero) technology-proving satellite.



Conclusion

I urged at the Rome Ministerial meeting at the beginning of 1985 the importance of balance in what we did in setting goals for Europe's future space programme. By "balance" I mean particularly balance between activities such as the development of launchers, manned space vehicles and Space Station activities which are the means of conducting space research and the achieving of more effective and attractive space services – the ends. We will not achieve the real fruits of space development unless we can continue to mount lively, relevant and well-timed utilisation programmes – in space science, in tele-communications in its different aspects, in Earth observation, in the potential new application areas of materials processing and so forth.

This should not be taken as a negative comment on Columbus/Space Station planning nor on Ariane 5 or Hermes or Hotol – but we do have to get our strategy for achievement and our timing correctly pitched if future ESA activities are to have the right span, if we are to make our goal of progressive European autonomy in space meaningful, and if the costs are to remain within affordable bounds in amount and in timing. And a central concern here is obviously the high cost and vulnerability to over-runs of manned space flight activities.

What started a quarter of a century ago as a muscle-flexing technological contest between the super powers has now blossomed into a major force for the advancement of mankind. Let us hope that we will be equal to the challenge it presents so as to maximise the opportunities for mankind that are undoubtedly there.

Space Centre Sets June Policy Target

by Roy Gibson

Roy Gibson

Newly appointed Director-General of Britain's National Space Centre, Roy Gibson, is now involved in drawing together the country's space interests and defining a long term plan for development and participation in national and international space projects. Below, Mr. Gibson writes for *Spaceflight* on the task ahead.

Why Organise Space?

At a press conference in London on November 20, the Minister of Information and Technology, Geoffrey Pattie, announced the formation of the BNSC and my appointment as its first Director-General. Readers of this journal will scarcely need reminding that this marked the end of a long campaign amongst space enthusiasts to have a focal point for the country's space activities. It had been traditionally held in the UK that space did not merit a separate organisation – government departments being free to use space as a tool, an instrument or a vehicle for its own activities, with coordination assured by a committee of representatives of the various departments.

So it has been for the past 20 years, and it has not worked so badly. The UK has many important space achievements to its credit and these should not be forgotten or belittled in the excitement that many of us feel in now having a national space organisation.

Why, then, is a space organisation needed at all? Many arguments have been brought forward over the years and I am not sure that all of them merit consideration. Avoiding duplication, for example, is often cited as one of the advantages. The new organisation will certainly enable a certain amount of rationalisation of resources and will help to facilitate communication between the various groups engaged in space activities in different parts of the country, but if any savings are to be found from this process, they are certainly offset by the cost of creating the central organisation – however slim we decide to keep it.

No, for me the overwhelming arguments in favour of having a national space organisation are to be found in the infinitely greater need there now is for a central national point in order to develop and to carry out a coordinated national space programme.

That is not to say that the space organisation need necessarily be responsible for every single space activity in the whole country, but it should certainly be aware of it and should have a word to say about any government funding it may require – and that in the light of an overall national plan.

In the same line of thinking, the space centre is needed to allow industry's needs and industry's contributions to be fed into the national plan in a timely way. Perhaps, for these reasons, it would have paid off to have had such an organisation some years ago, but the need is very much greater now because of the inter-dependence of space programmes.

We are no longer in the era where it was possible to decide on satellite programmes one by one, and with little thought of their relationship one to another except for the total bill. Nowadays, particularly with the advent of the Space Station, we need to have an agreed overall framework for our space activities. We cannot possibly do half the things that many people would like to see included, but those which we think we can afford must together make sense.

Moreover, there must be enough money left in the national till for us to be able to use properly the facilities which we have created or helped to create through international cooperation.

And so this will be the first priority of the British National Space Centre: the production of a national space programme. Our target for this is the end of June – perhaps I should, for the cynics, add 1986.

Building Up the Organisation

Of course, the first task is to get organised. The BNSC has inherited contributions from a number of major participants, and these have to be put together in a sensible way. The principal initial contributors are the following:

Department of Trade and Industry, of which the Space Division headed by Mr. Clifford Nicholas is transferred to BNSC forthwith, as well as Mr. Jack Leeming, the Under Secretary who has done so much to bring about the formation of the BNSC. He is now the Director of Planning and Programmes. Joining him in his Directorate are not only his colleagues from DTI but also senior staff seconded from the other major contributors: SERC, NERC, and the Ministry of Defence.

SERC is also seconding a significant number of staff from the Rutherford and Appleton Laboratory.

NERC is seconding staff, principally in the remote sensing area, to serve with BNSC at RAE, Farnborough, and in London.

Ministry of Defence is seconding a major part of the Space Department at Farnborough.

This will mean that the BNSC has somewhat over 300 staff seconded from its founders, and these will be managed by the DG, the Director of Planning and

Programmes previously mentioned, plus a Director of Projects and Technology still to be appointed.

The London office is in Millbank Tower on the Thames at Westminster, and the other personnel will be located at RAE or at RAL – with the minimum movement of personnel consistent with an acceptable organisation.

Due to the nature of the parent organisations, not all of the personnel seconded from the laboratories can, at least in the first instance, be full-time, nominated persons. It is envisaged that some of the manpower will be provided in the form of man-years: it would be impracticable, indeed undesirable, for the BNSC to attempt to be wholly independent in all the specialities it will need. Far more important than the supposed prestige which might be attached to having a larger number of BNSC badge-bearing personnel, is the need to have a logical organisation with sensible long term arrangements with the host laboratories.

Looking Ahead

Another priority task of the BNSC management in the first few months of its life is to recommend what sort of a beast it should become. It exists at the moment thanks to the cooperation of a number of government departments and government funded organisations, but it will need to have its status more clearly defined over the coming months.

This is probably an appropriate moment at which to emphasise the excellent spirit of cooperation which I have found in the weeks since I took up this new post. At all levels I have found nothing but cooperation – much more than I could ever have expected. I realise that this is a sort of honeymoon period and that the BNSC must soon show what advantages it has brought, or will shortly bring, to its contributors, but the constructive atmosphere in which all this is taking place deserves to be known to a wider circle.

Some readers may have noticed that I have not so far made much mention of industry's role in the BNSC. This is not at all because of the BNSC does not need industry's help – quite the contrary, but it is only reasonable for industry to be able to see exactly what is planned and how programmes will be executed, before asking for their substantial financial and material support. In the short term, there is a real need for help from industry in the form of short secondments of specialist personnel to serve on the BNSC's planning group and to help put together a plan which industry will later feel able to support. I am confident that this help will be available from industry.

Many journalists, particularly those from the Continent, have asked whether the formation of the BNSC heralds a move away from the European Space Agency, and of course this is certainly not the case. Space programmes will continue to be extremely costly, and it makes good sense for us to be doing most of this work with our European partners.

Perhaps we are hoping to be a little more discerning in our choice of the morsels which come our way in these cooperative programmes; perhaps we need to have a higher profile in the European decision making, but these are ambitions for the future. In the mean time there is much to be done to identify what it is we want out of our space effort and expenditure, and this will be our number one priority as these lines are being read.

Thanks for Your Support

May I take this opportunity of thanking the British Interplanetary Society for its active support over the years for the concept of a British National Space Centre. Many members in all parts of the country have already written expressing their satisfaction. My colleagues and I can make no promises other than to assure you all that we are full of enthusiasm, and that the expressions of support we are receiving both from inside the country and from abroad make us sure that no-one will regret the November decision.

Space Bill Goes Before Parliament

Lord Lucas of Chilworth, Parliamentary Under-Secretary of State for Trade and Industry, has introduced a Bill to enable the United Kingdom to fulfill certain international obligations concerning private sector activities in outer space.

The obligations arise under three United Nations conventions to which the UK is a party: the 1967 Outer Space Treaty, the 1972 Convention on International Liability for Damage Caused by Space Objects and the 1976 Convention on Registration of Objects Launched into Outer Space.

These conventions oblige the Government to exercise a measure of supervision over private sector activities in outer space; to pay compensation if such activities cause damage to foreign states or persons; and to enter details of private sector satellites into a register of "space objects".

Describing the Bill, Lord Lucas said: "In the past, the launch of satellites and their operation was seen as the job of the public sector or of international organisations. This view is changing and today the prospect of a UK private sector satellite project no longer seems remote. We have therefore decided to introduce legislation to enable us to fulfill our international obligations in respect of private sector activities in outer space, when they occur.

"This legislation will allow the private sector to plan outer space projects with knowledge of how the legal framework will operate. It will apply to all commercial, scientific and experimental satellite projects unless they are carried on by an arm of Government.

"The Bill introduces the minimum of regulation necessary for us to meet our international obligations."

A non-statutory register of space objects has been kept since 1976 and the only non-Governmental space objects registered are satellites owned by the Science and Engineering Research Council (SERC) and by the University of Surrey. The continued operation of these satellites will eventually need to be licensed (although the Bill does contain transitional provisions). SERC is likely to be given one "open licence" covering all its science projects in outer space.

There are a growing number of private sector satellites in the United States but there is no imminent private sector satellite project in the UK.

Administration of licensing will be carried out by existing staff working in the British National Space Centre and costs incurred will be recovered from fees.

UNITED KINGDOM

Mr. Tom Mayer, CBE, Chairman of the United Kingdom Space Committee (UKISC) since 1984. Mr. Mayer, who from April 1 becomes Chief Executive of THORNE EMI Technology, is a founder member of UKISC and has been closely involved in its work since 1975.

UKISC

The United Kingdom Industrial Space Committee (UKISC) represents the British Companies which have activities in the Space Sector. The committee is jointly formed from members of the Society of British Aerospace Companies and the Electronic Engineering Association to represent companies involved in a whole range of Space activities, from launcher guidance and satellite construction to ground stations for telemetry and communications. The companies are engaged in design and manufacture of both hardware and software for many different programmes. Within UKISC there are 14 participating members and three corresponding members.

Industry Invests in Space

by Tom Mayer, CBE

The major role of British companies in space-related programmes was highlighted in a presentation to UK diplomatic staff in London during February. The audience comprised Foreign and Commonwealth Office staff about to take up new duties at UK diplomatic posts overseas. A two week long series of specialist briefings updated them on the capabilities of all apsects of the British Aerospace Industry. We are pleased to present here a short summary of Tom Mayer's overview of the wide-ranging activities of British companies in space.

The British Space Industry

Following the cancellation of the British launcher programme 20 years ago, Industry has concentrated on the electronics and high technology aspects of the business and has particularly excelled in the construction of satellites and the ground station elements of a number of key programmes. Support of major ESA activities has been a critical element of the work carried out, and key contributions have also been made to NASA programmes and to a number of projects for countries in the Middle East. Industry is looking forward to increasing its export business to countries who have activities concerned with any aspect of Space, in communications, navigation, meteorology or Earth resources mapping.

The contribution that British Industry makes to ESA programmes is indeed the foundation of our Space business. Following the recent review of the British national contribution to the ESA budget, the Government is committed to an expanding programme of support for European programmes including the joint ESA/NASA activity on the Space Station. During the last 20 years British industry has contributed to the European programme in more than 30 projects. These include:

HEOS	Studies of interplanetary magnetic fields
ISEE	Research in the Earth's magnetosphere
GEOS	First ESA satellite for which UK industry took prime responsibility in 1977
METEOSAT	Weather satellite
OTS	Experimental satellite TV transmission
EXOSAT	Location of X-ray sources
SPACE TELESCOPE	For detecting very faint stars

And shortly to be launched are:

ISPM	For exploration of Solar Poles
HIPPARCOS	To measure star motion
ERS 1	Remote sensing of oceans and coastal areas

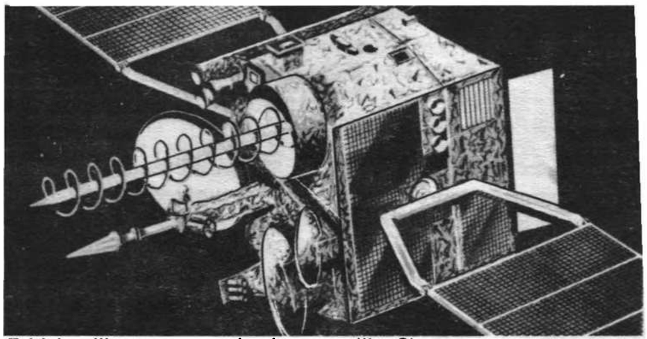
The wide scope of design and manufacture to support the ESA programme requires a large investment in the creation of very comprehensive manufacturing and test facilities. All such facilities are located within British Industry and give a comprehensive capability to the UK for Space projects.

Military Satellites

In the military field industry has concentrated on the supply of communications satellites and ground stations. In this review it is not possible to go into the detail of the facilities provided to the Armed Services which include voice transmissions, data communications and visual images. The very advanced series of Skynet satellites together with the ground equipment which include large antenna stations and vehicle and man-portable equipment enable communications to be made between land, air and sea. Work on military satellites also includes meeting the needs of NATO.

Applications Satellites

Many satellite programmes have been concerned with Earth observation either to obtain meteorological data or to carry out terrestrial surveying for minerals or mapping. These missions are accomplished using satellites which either orbit the Earth continuously covering the whole of the surface, or are fixed in


British military communications satellite Skynet.

geostationary orbit over a particular sector of the globe. Typical orbiting satellites are Meteosat used for weather forcasting, Landsat used for terrain mapping and ERS1 used for Earth resources measurements. An important business aspect of this work is the supply of the large number of ground stations all around the world to enable the agricultural, fishing and mineral extraction agencies to determine the best conditions for their operations.

Another key use of satellite systems is to provide a method of global navigation. The NAVSTAR system provides mobile units on land, sea and in the air with an ability to fix their position to an accuracy of a few metres using small, low cost ground stations.

Communications Satellites

Today, telephone calls can be routed via Space over thousands of miles at a lower cost than a terrestrial link of only a few hundred miles.

The existing ECS satellite supports communications within the whole of Europe. Its use highlights the astounding growth in communications over the last 50 years. In many parts of daily life, technology has had a profound impact. For instance, the speed of transport has increased perhaps 10 times and agricultural efficiency by a similar factor. In communications terms however the improvement in signal capacity and distance travelled has increased by a factor of a million or more. This prodigious capability, by which for instance a whole continent such as North America can receive simultaneously 50 television programmes from Space, shows quite astounding growth. The ECS satellite scored a first in Europe by providing the commercial relay of television programmes.

Scientific Satellites

Some of the most spectacular successes of the Space programme have been the scientific missions in which the galaxy has been explored by telescopes, infrared and X-ray cameras. The recent mission to Uranus and the rendezvous of the Giotto probe with Halley's comet captured the public imagination but do not perhaps lead to the same prospects for export sales as other Earth-related programmes.

Ground Equipment

The greatest potential for expansion in Space equipment for commercial use is the growth of the use of satellites, especially geostationary satellites, for voice, data and television communications. Not only do British companies make the satellites used for many of these transmissions but they also provide the complex ground equipment used to uplink the calls, data and programmes and the simpler receiver-only equipment for cable head end for business and domestic use. The whole area of ground stations is one of great potential for British industry.

A single satellite system can generate a market for thousands of ground stations covering wide areas of the globe. Some of the installations already in place are Goonhilly 1, Goonhilly 2, Madeley (where the red brick building is full of electronics – one notices the dish but the expensive equipment is indoors!) and the installation at Masirah.

Links are provided to serve many Government communication needs and our Embassies abroad are all equipped with up-to-date equipment of British design and manufacture.

Looking to the Future

Although much of the work of British Industry in recent years has been in association with ESA it is important to establish a continuous involvement with the enormous USA Space programme. The UK Government is a leading supporter of the ESA initiative in contributing to the US Space Station. In addition to many other projects, UK industry is planning involvement in polar orbiters and in data communications associated with the commercial exploitation of the Space environment, for the production of new materials in gravity free envionments.

Three of the many projects in which UK companies are actively engaged with NASA are: The Space Station: The Space Telescope project: and Gamma Ray observatory in Space.

One of the most topical programmes associated with Space activities is the US Strategic Defence Initiative. Very recently a Memorandum of Understanding was signed by the UK and US Governments in support of a British contribution to the programme. Within the next few weeks British Industry will be outlining to US Departments of Defense and Industry how our capability, built up in recent years in all aspects of Space-related technology, can be developed to carry out a number of the research tasks to be funded by the US Department of Defense.

It may come as a surprise to many people to realise how much the activities of British Industry have contributed to the Space business. We have perhaps as an Industry been lacking in public visibility but Industry views the Space market as very important in generating a large export business.

Following discussions with the British Government over the past few years, Industry was delighted by the decision to set up the British National Space Centre (BNSC) under the direction of Roy Gibson. Detailed plans for the work of the centre are now being prepared and Industry has pledged to give its full support to the preparation and implementation of the National Plan. The BNSC is critically reviewing future British activities in Space and one of the important projects is the proposed polar orbiting Space platform associated with the NASA Space Station.

In this short overview I have discussed the achievements and capabilities of industry in Space and outlined the solid foundations on which we intend to base our future business. There is a wealth of talent in industry seeking to exploit new technologies and HOTOL is just one of the exciting new concepts we are looking at for the future.

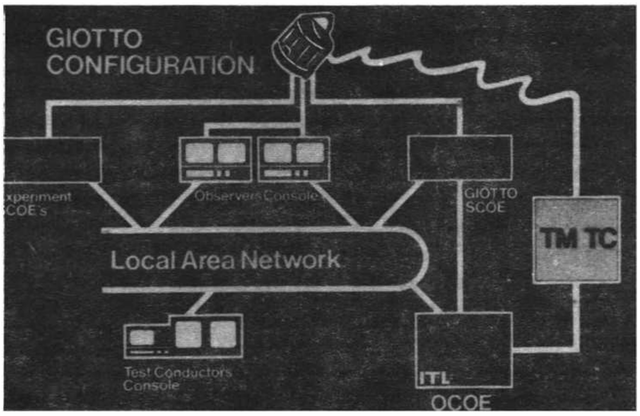
British Super-Minicomputer Boasts Reliability

Information Technology Limited is a leading British computer company which researches, designs, manufactures, sells and services a wide range of advanced computer and communications products for business, industry, science and government through its own nationwide network of 16 sites.

The Information Technology Limited Momentum 9000 super-minicomputer at the European Space Operations Centre is capable of processing and distributing vast quantities of telemetry data at high speeds despite having only 0.75 megabytes of main memory. Momentum was used as the develcpment base for ETOL, the European Space programming language, which allows scientists and engineers to program their applications without needing to be computer specialists. It is currently monitoring the health and housekeeping of the Giotto satellite mission to Halley's Comet.

When the European Space Agency first started using Momentum or its predecessors for satellite testing and monitoring, its standard procedure was to buy two computers in case one failed. Soon after working with the Momentum, however, this requirement was abandoned. Even on so critical a satellite as Giotto, where years of work and tens of millions of pounds have been dedicated to achieving a mere 30 minute conjunction of satellite and comet after a nine-month flight, ESA only found it necessary to buy one Momentum computer. No satellite program using ITL computer systems has ever been delayed by ITL computer failure.

Momentum will feed continuous data on 2,000 parameters relating to the status of Giotto and its 10 experiments through an ITL Cablestream Local Area Network selectively into 10 other computers – from Apples to DEC PDP-11s. Momentum's selectable multi-colour synoptic displays of each satellite sub-system also make satellite and experiment status visible and adjustable without mountains of printouts. Cablestream is a range of ITL equipment which makes



up Europe's most popular broadband cable local area network and is used by a considerable number of industrial and commercial giants.

When the European Space Agency commissions a new satellite from a European prime contractor and sub-contractors spread throughout Europe, it is built on a Cablestream Local Area Network (LAN) which connects the satellite test equipment to a resilient Momentum and to the satellite and its battery of experiments. This network then tests out the satellite's system and experiments under the control of the Momentum. During this process, not only the ESA satellites but their entire Cablestream LANs and Momentum computer systems are often required to be transported, heated up, cooled down, subjected to vacuums, and severely shaken. In fact, Momentum is the only equipment ever to have passed the ESTEC-defined EMC tests (electro-magnetic compatibility), in which it has proved it can keep operating while subjected to varying strengths and combinations of magnetic emanations, electrical current fluctuations, wide temperature variations and air cleanliness degradation. More than 20 British, Italian and ESA satellites, including Giotto, have been built using the Momentum/Cablestream system

SATELLITES IN EDUCATION

The University of Surrey has catalysed an initiative in the UK to promote the specific use of satellites in education – involving not only the two UoSAT spacecraft but also meteorological, TV and other satellites that are readily available to the individual experimenter.

As reported in *Spaceflight* (March 1986, p116), a UK Coordinating Committee for Satellites in Education was created in early 1985 comprising representatives from all strata of education. It is currently under the chairmanship of Dr. John Gilbert.

A national resource centre is planned to be established at UoS to support this programme which is intended to provide a central coordinating team, to assist in the preparation of materials, experiments and software, and to advise on hardware focussing directly on educational applications.

It is anticipated that there will be opportunites quite soon for a small number of science teachers to join or be seconded to UoS to develop the centre and educational resources. Any qualified teachers who may wish to be considered should contact Dr. John Gilbert at UoS.

BOOK REVIEW

History of British Space Science •

H. S. W. Massey and M. O. Robins, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 514 pp, 1986, £45.00.

This book documents how a new and complex branch of science emerged within the UK and was encouraged to grow both nationally and internationally, as seen through the eyes of two who played a major role in many of the events described.

It traces the beginnings of the British Space Science programme from its origins in the 1950's up to the 1980's, providing both information about its background and highlighting some of its successes. Cooperation with NASA is described in some detail, as well as the part played by Britain in establishing European collaboration and a more modest collaborative programme with Commonwealth countries.

It is interesting to note that, during this 30 year period, British science experiments were carried aboard more than 600 rockets and 37 spacecraft.

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

EURO BUSINESS FOR CHINESE

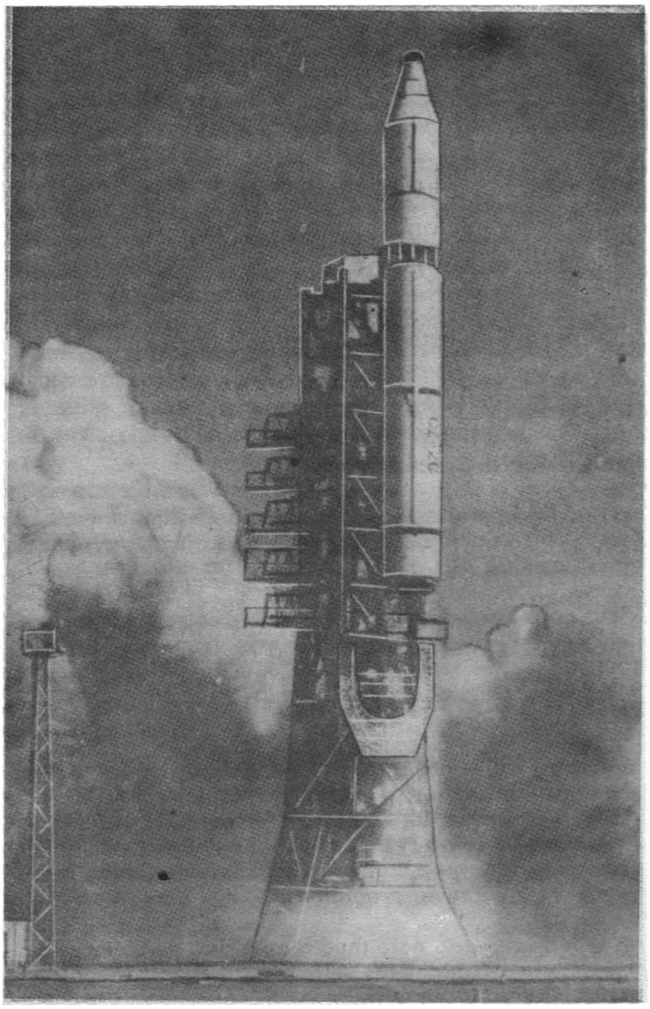
Sweden is considering use of the Chinese launcher Long March 2 for its proposed Mailstar satellites.

A one year launch reservation agreement has been signed between the Swedish Space Corporation and China. If it goes ahead the contract would be one of the first commercial launch agreements secured by China.

Mailstar, a small satellite being evaluated for electronic mail service to parts of the world where the telecommunications infrastructure is under-developed, would be launched piggyback with a Chinese Earth observation spacecraft.

These are placed in low Earth orbit by Long March 2 and an extra propulsion system would be needed by Mailstar to boost it to operational altitude. Joint work is currently taking place to design an appropriate propulsion system.

Launch of China 17 last October by the Long March 2 rocket which could be used for Sweden's Mailstar satellite.



1986 NASA LAUNCHES

NASA has five launches of unmanned rockets scheduled for the remainder of 1986 from Cape Canaveral. They are:

- May 1 – GOES-G weather satellite aboard a Delta rocket.
- May 22 – Navy communications and navigation satellite aboard an Atlas Centaur.
- Aug 14 – DoD payload aboard a Delta rocket.
- Oct 9 – GOES-H weather satellite aboard a Delta rocket.
- Nov 16 – Navy communications and navigation satellite aboard an Atlas Centaur.

JAPANESE DBS

RCA is to design and manufacture major subsytems for the BS-3 Spacecraft bus as a part of Japan's third generation direct broadcast satellite. RCA is under contract from NEC Corporation of Japan, who have worked together on the Broadcasting Satellite programme since 1981, ***writes Nicholas Steggall.***

BS-3 will provide three broadcast channels to all of Japan and its nearby islands. Two channels will carry NHK (Japanese Broardcasting Corporation) programmes and one channel will carry programmes from the Japan Satellite Broadcasting Inc., a conglomerate of private companies which will share the capital.

NASDA has contracted for two satellites to be launched in the summer of 1990 and 1991 by the H-1 launch vehicle now under development.

HISTORIC TRANSMISSION

Live television was brought to the high seas for the first time at the end of January by the American-based Communications Satellite Corporation, Comsat.

The American Super Bowl Game was transmitted live to Cunard Line's Queen Elizabeth 2 which was at sea in the Pacific Ocean.

It was organised to demonstrate the technical feasibility of relaying television programming via the Inmarsat satellite system to ships at sea and offshore drilling rigs.

However, since the live transmission of the popular sporting event took place during the ship's dining hours Cunard chose to video the game for a showing later the same evening!

SATELLITE DIGEST – 191

Robert D. Christy

Continued from the March 1986 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1713, 1985-120A, 16434.

Launched: 1705, 27 Dec 1985 from Plesetsk by A-2.
Spacecraft data: as Cosmos 1702.
Mission: Possibly a space engineering applications mission.
Orbit: 216 x 398 km, 90.67 min, 62.82 deg.

COSMOS 1714, 1985-121A, 16437.

Launched: 0920, 28 Dec 1985 from Tyuratam, possibly by a version of the D vehicle.
Spacecraft data: not available.
Mission: Possibly a failed launch of a large electronic intelligence gathering satellite.
Orbit: 443 x 853 km, 97.72 min, 70.99 deg, although another object (catalogue number 16434) may be the payload in an orbit of 163 x 850 km, 94.75 min, 71.00 deg.

COSMOS 1715, 1986-1A, 16447.

Launched: 8 Jan 1986 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft, with spherical re-entry module, instrument unit and a supplementary package of instruments at the forward end. Length about 6 m, diameter (mas) 2.4 m, and mass around 6000 kg.
Mission: Military photo-reconnaisance, recovered after 14 days.
Orbit: 227 x 283 km, 89.65 min, 72.82 deg.

COSMOS 1716-1723, 1986-2A-H, 16449-56.

Launched: 0249, 9 Jan 1986 from Plesetsk by C-1.
Spacecraft data: Each satellite is possibly spheroidal in space, about 1 m long and 0.6 m diameter, and with mass approx 40 kg.
Mission: Single launch of eight satellites to provide tactical communications for troops or units in the field.
Orbits: 1480 x 1698 km, 118.00, min, 74.00 deg (lowest), 1475 x 1515 km, 115.91 min, 73.99 deg (highest).

STS-61C, 1985-3A, 16481.

Launched: 1155*, 12 Jan 1986 from the Kennedy Space Centre.
Spacecraft data: Shuttle Orbiter 'Columbia'.
Mission: Carried crew of Gibson, Bolden, Nelson, Hawley, Chang-Diaz, Cenker and Nelson (US Congressman). Mission objectives included materials science experiments, tests of SDI related surveillance equipment and launching a communications satellite. 'Columbia' landed on the runway at Edwards AFB at 1359, 18 Jan 1986.
Orbit: 324 x 346 km, 91.05 min, 28.47 deg.

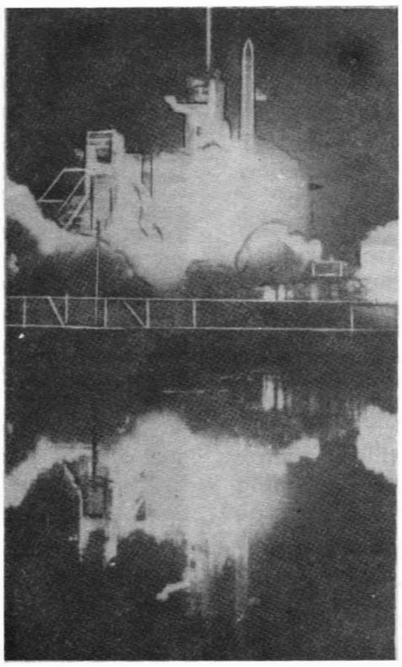
RCA SATCOM K1, 1985-3B, 16482.

Launched: 2125, 12 Jan 1986 from the payload bay of 'Columbia' by PAM-D2.
Spacecraft data: Three-axis stabilised, box shaped body, 1.7 x 2.1 x 1.5 m, with a 15 m span solar array and mass around 1100 kg.
Mission: Commercial communications satellite.
Orbit: geosynchronous above 85 deg west longitude.

COSMOS 1724, 1986-4A, 16490.

Launched: 1420, 15 Jan 1986 from Plesetsk by A-2.
Spacecraft data: as Cosmos 1715.
Mission: Military photo-reconnaissance.
Orbit: 169 x 332 km, 89.54 min, 67.15 deg, manoeuvrable.

The spectacular night launch of Shuttle Columbia on January 12, 1986.



COSMOS 1725, 1986-5A, 16495.

Launched: 1139, 16 Jan 1986 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a drum shaped solar array with length and diameter both about 2 m. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 972 x 1003 km, 104.91 min, 82.94 deg.

COSMOS 1726, 1986-6A, 16495.

Launched: 0723, 17 Jan 1986 from Plesetsk by F-vehicle.
Spacecraft data: not available.
Mission: Electronic intelligence gathering.
Orbit: 632 x 663 km, 97.74 min, 82.53 deg.

RADUGA 18, 1986-7A, 16497.

Launched: 1020, 17 Jan 1986 from Tyuratam by D-1-E.
Spacecraft data: Cylindrical with a pair of solar panels at right angles to the body, and an aerial array at one end. Length 5 m, diameter 2 m, and mass around 2000 kg.
Mission: To provide round the clock radio, television and telegraphic communications within the Soviet Union through the 'Orbita' system.
Orbit: geosynchronous above 25 deg west longitude (Statsionar 9).

COSMOS 1727, 1986-8A, 16510.

Launched: 1853, 23 Jan 1986 from Plesetsk by C-1.
Spacecraft data: as Cosmos 1725.
Mission: Navigation satellite.
Orbit: 962 x 1016 km, 104.95 min, 82.95 deg.

COSMOS 1728, 1986-9A, 16512.

Launched: 0835, 28 Jan 1986 from Tyuratam by A-2.
Spacecraft data: as Cosmos 1715.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 225 x 273 km, 89.52 min, 69.97 deg.

UPDATES:

1985-109D, name should read **'RCA SATCOM K2'**
1985-112A, Cosmos 1706 re-entered or was recovered 9 Feb 1986 after 60 days.
1985-120A,. Cosmos 1713 was recovered 22 Jan 1986 after 26 days.

Space Station – Build-up Begins

The new Soviet initiative in manned spaceflight comes at a time when the United States manned programme is still reeling from the crisis following the Challenger disaster.

On March 12, the Soviet space programme broke with tradition and gave its first advanced notice of a space launching scheduled for the following day. The mission was the first of a series of launchings to the new Soviet space station, Mir, which was placed in orbit on February 20.

The start of manned operations at the space station is to be led by veteran cosmonaut Leonid Kizim and space endurance record holder Vladimir Solovyov. Long-term occupation of the space station is indicated by the 252 and 237 days of space experience already credited to the cosmonauts. The Soviet spacecraft involved in the 13 March launching was Soyuz T-15.

The new space station has six docking ports for manned or unmanned capsules ferrying to and from the Earth. Its launch, by a Proton booster, is seen as the first stage in Soviet plans to form a new modular space station complex. Shortly after launch a manoeuvre to correct the orbit was completed. Four days later Tass reported that everything was going to plan and a series of control tests on the structure and on-board systems were being carried out.

The Space station is currently in a 352 km by 324 km orbit, with a period of 91.6 minutes and an inclination of 51.6 degrees.

Vladimir Solovyov

Leonid Kizim

Control of Mir and the previously in orbit Salyut 7 is being conducted by the mission control centre in Moscow with help from tracking stations in the Soviet Union and research vessels.

The new station represents a third generation Soviet space laboratory and it will mark the beginning of a transition from experimental research to large scale production activities in outer space. Experts believe that one of its uses will be for the production of semi-conductors.

Each of the space station modules has purpose-orientated functions for uses ranging from technological production to biological research.

For the first time in a space station occupants will be able to retreat to the privacy of their own cabins which each contain a desk, arm-chair and sleeping bag.

The new station has two solar array wings mounted on the middle of the vehicle, unlike the previous Salyut design which used arrays on three sides.

VEGA PROBES ENCOUNTER HALLEY

Instruments onboard the Vega 1 spacecraft were activated and its tracking platform located Comet Halley, directing TV cameras towards it for the first time on March 4.

Vega 1 was at a distance of 14 million kilometres from Halley and 171 million kilometres from Earth.

For 90 minutes the TV cameras on the tracking platform transmitted pictures of the comet taken through various filters.

Two days later Vega 1 passed through the gas and dust envelope of Comet Halley at a distance of some 9,000 km from the nucleus.

For the first time ever instruments recorded large-scale images of the nucleus together with measurements and analysis of the chemical compostion of the gas and dust.

During the three hour session of scientific measurements and photography Vega 1 flew past the nucleus with a relative velocity of 80 km per second. More than 500 TV pictures were transmitted to Earth during the encounter.

The spacecraft was not seriously damaged and according to post-encounter telemetry signals was functioning normally after flying through the gas and dust.

Vega 2, the second Soviet probe, encountered Halley on March 9.

Scientific instruments on the two spacecraft were developed jointly by the Soviet Union, Austria, Bulgaria, Hungary, Germany, Poland, France and Czechoslovakia.

ATLAS OF VENUS

Soviet Scientists have compiled an atlas of Venus which includes 20 maps, each measuring three square metres. They have been drawn up from the data of radar probing carried out by the Venus 15 and Venus 16 interplanetary stations which took photographs of the surface of the planet every day during almost a year, from October 1983 to July 1984.

Geologists believe that, judging by photographs, the surface of Venus resembles that of Earth. Mountain ranges and valleys, volcanic peaks and craters are visible. Scientists have also detected signs of tectonic activity like that on Earth.

The highest mountain on Venus is 11.5 kilometres and the planet also has a large mountain range stretching from north to south over several hundred kilometres. Two huge craters with a diameter of 15-20 km each are marked on the maps. Scientists believe that they were caused by the impact of celestial objects onto the surface.

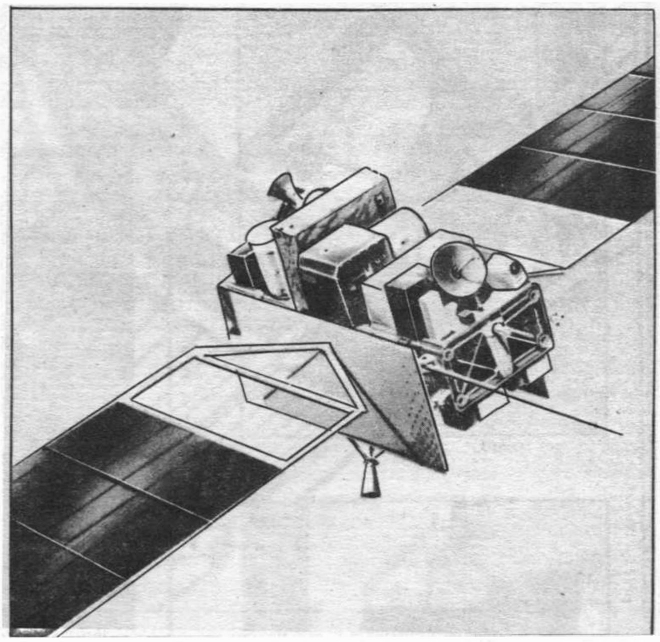
EUROPEAN RENDEZVOUS

MARCONI COMMUNICATIONS

The French Space Agency (CNES) has awarded Marconi Space Systems of the UK a contract to develop and supply communications equipment for launch on the ESA platform Eureca – the European retrievable carrier. This contract covers a major contribution to the inter orbital communications experiment.

The Eureca platform is due to be launched from the NASA Shuttle in 1988. It is planned to carry out a six month mission during which automatic experiments will take place in microgravity. Eureca will then rendezvous with Shuttle for recovery and return to Earth.

The Marconi communication equipment operates at EHF and by using a steerable antenna and tracking system will enable data to be passed from Eureca to a geostationery communications satellite some 24,000 miles distant. For the first mission Eureca 1 will communicate through the ESA satellite Olympus, also due to be launched in 1988. This will constitute the European Space Agency's first demonstration of communications between two satellites.



The European retrievable payload carrier, Eureca, will encourage commercial space activities. *ESA*

The Mediterranean coastline in the region of the Nice Riviera as seen by the French Spot satellite after being placed into orbit by an Ariane 1 launcher on February 22. The image has a ground resolution of 10 metres and streets of Nice can be seen.

SOHO AND CLUSTER

ESA's Science Programme Committee has given unanimous approval to the Soho and Cluster missions which together form the Solar Terrestrial Physics cornerstone of ESA's long-term scientific plan.

In coming months the Agency will request the scientific community to put forward proposals for experiments to be carried on-board these missions. These proposals will be evaluated early next year and the complete mission will be presented to the Science Programme Committee before the start of detailed systems studies and pre-development work (Phase B) in 1988.

With the choice of the Soho and Cluster missions, work on the first of the four cornerstones, the Solar Terrestrial Physics Programme, will now get underway.

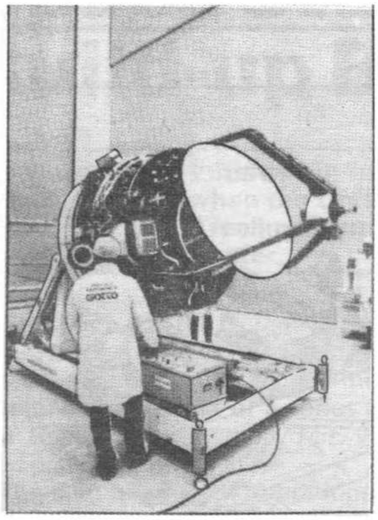
Soho (Solar and Heliospheric Observatory) is a multi-disciplinary mission designed to investigate, using remote sensing techniques, the outer layers of the Sun, to measure, in situ, the solar wind streams and associated wave phenomena and to probe the interior structure of the Sun by monitoring the velocity and luminosity oscillations of the solar surface.

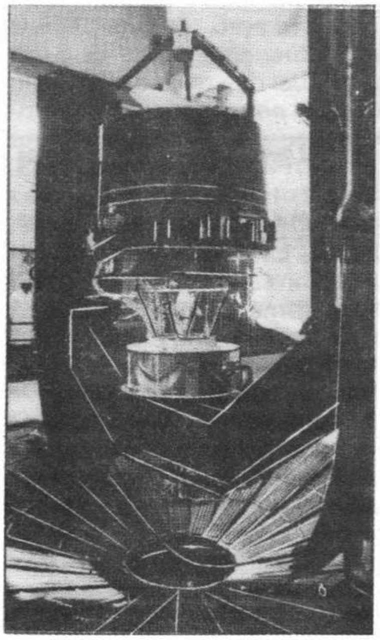
The Cluster mission has been designed primarily to study small-scale structures in the Earth's plasma environment and the associated turbulence. Cluster takes its name from the fact that the mission will consist of four spacecraft orbiting in different planes in the Earth's magnetopause, geomagnetic tail and plasma sheet.

Present planning foresees the launch of the five spacecraft in the 1993-1995 time frame.

SUCCESS FOR EUROPE'S

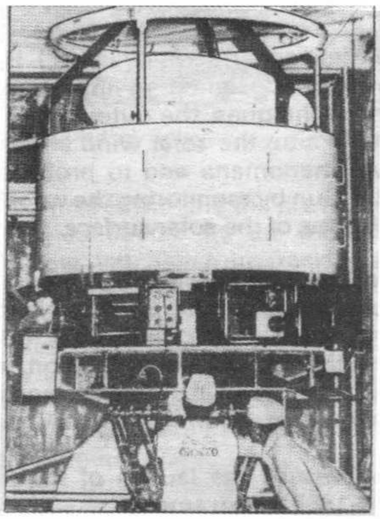
Close Enc

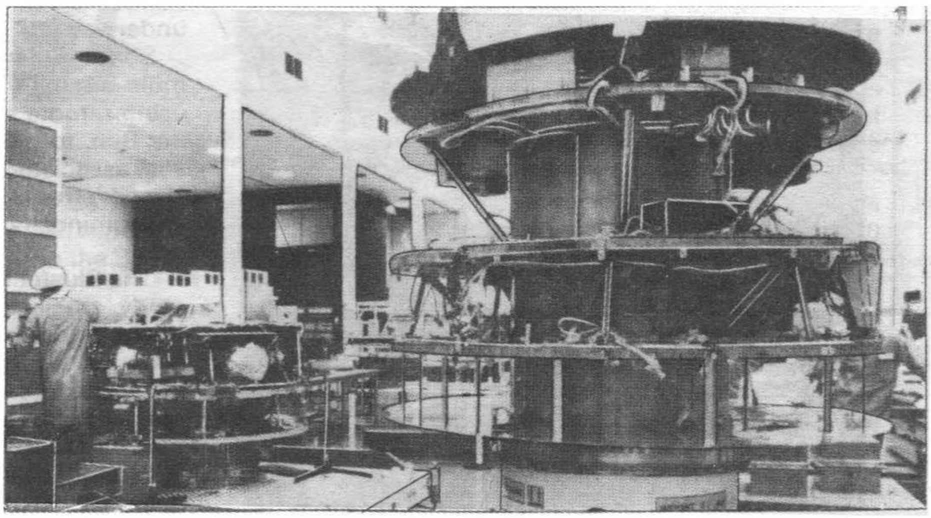




One of the first pictures returned by Giotto shortly before midnight on March 13 as it homes in on the Comet Halley nucleus.

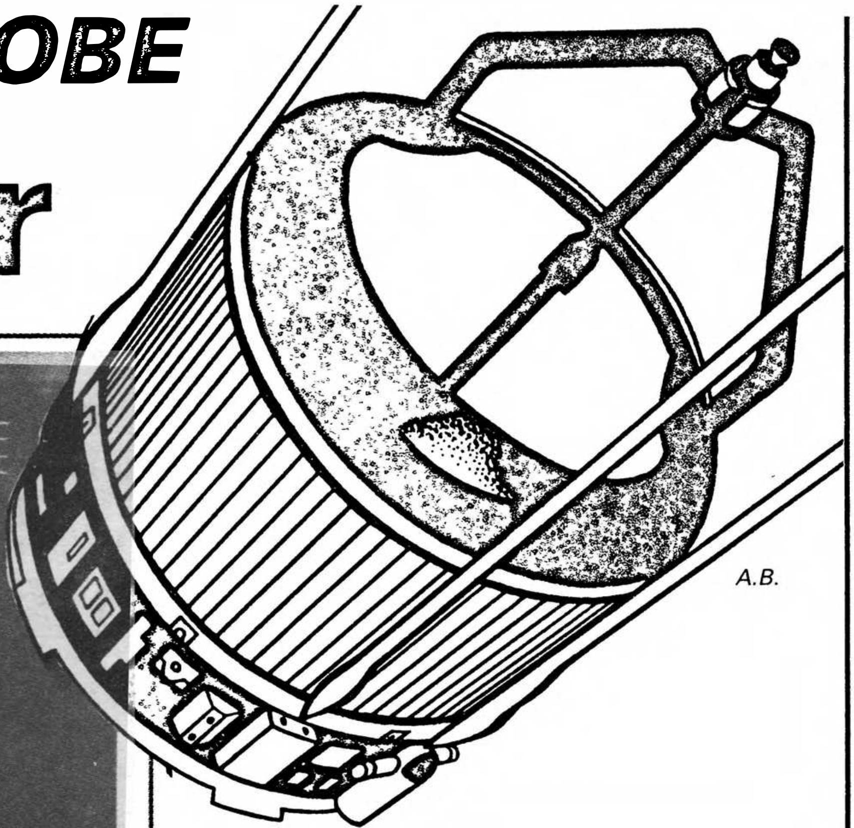
The contouring effect is caused by false colour processing to highlight



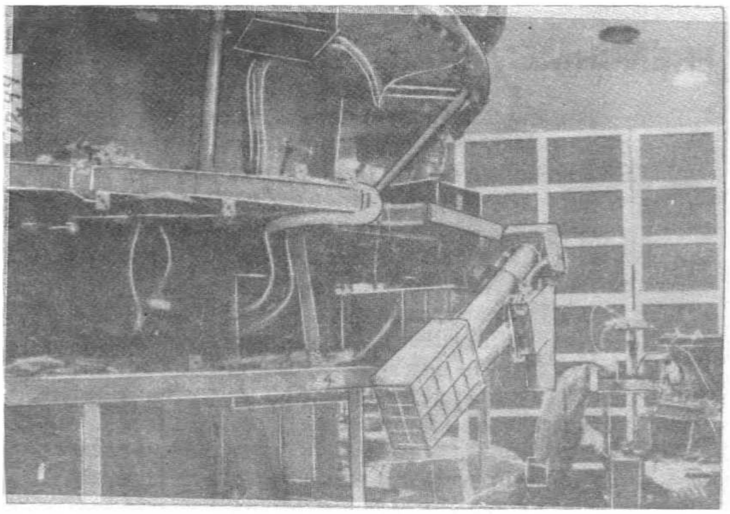


HALLEY PROBE

ounter



areas of varying light intensity. The pictures left and below show the Giotto spacecraft at various stages of testing and development by British Aerospace.



The Giotto spacecraft, built by British Aerospace on behalf of the European Space Agency, performed perfectly during the interception of Halley's Comet on March 13, 1986.

The mission was regarded as a complete success by the scientific investigators for whom it was designed. All experiments performed as intended and returned high quality data.

Giotto passed within 540 kilometres of the comet's nucleus but seconds before the closest approach and the end of the mission, Giotto was hit by cometary debris which caused it to oscillate and prevent further pictures being taken.

After about 40 minutes, Giotto's active damping system stabilised and enabled operations to continue. From this time of full recovery – which was well after the mission's planned conclusion – further data from Giotto was regarded as a bonus by Mission Control at the European Space Operations Centre in Darmstadt.

Giotto was damaged by its collision with particles from the comet and there were many penetrations of its protective bumper shield but it is believed to remain sound.

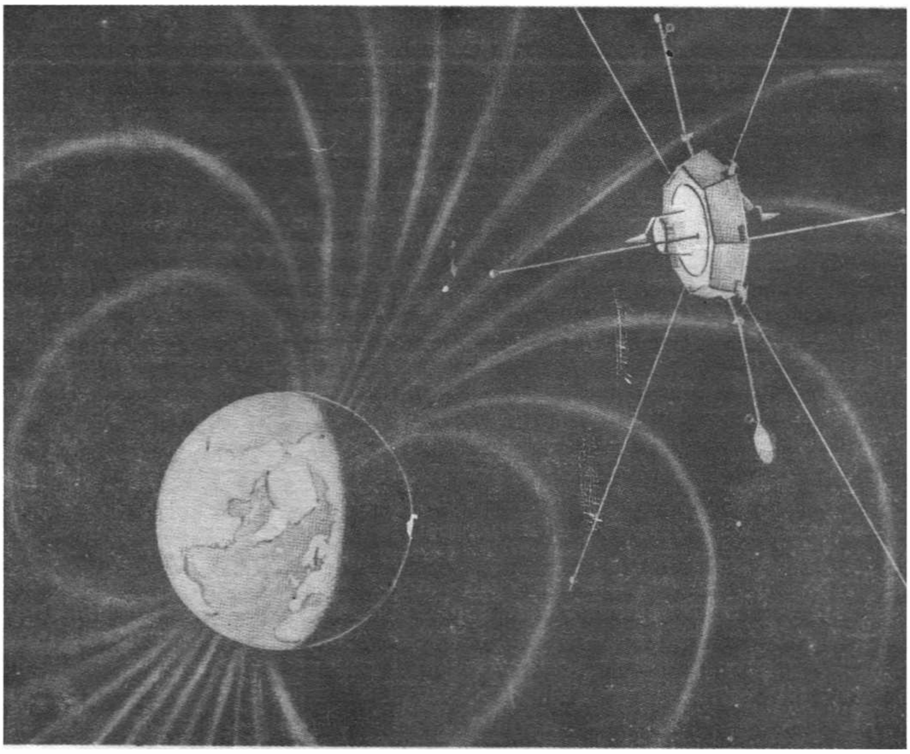
The full implications of this spectacular encounter are being investigated, but it is understood that there is no damage to the de-spin system or degradation of the solar cells. The star mapper, which provides data on the spacecraft's position in space, was damaged but is still functioning.

The surface of the comet nucleus was much bigger and darker than predicted by scientists. It measured 9.3 miles by 2.5 miles compared to estimates made by the Soviet Vega probes of 6.8 by 4.3 miles.

● A full report of the Halley comet encounters with more pictures will appear in the next issue.

EUROPEAN RENDEZVOUS

VIKING IN ORBIT



Sweden's first scientific satellite, designed to study the Earth's magnetosphere, was launched in tandem with the French Earth-resources satellite aboard Europe's Ariane launch vehicle from Kourou, French Guiana, on February 22.

During its eight-month mission, Viking (pictured right) will study space plasma phenomena, believed to be responsible for the aurora borealis, in the Earth's magnetoshere. This is of special interest to higher-latitude countries because the aurora borealis phenomenon, also known as the Northern Lights, disturbs radio communications and other electronics.

Apart from the scientific mission Viking was from the beginning also meant to be a learning project for Swedish industry in the field of satellite services. Thus the Swedish company Saab Space was awarded prime contractorship for the satellite with Boeing Aerospace Company as main subcontractor.

EXOSAT ON WAY BACK

The European X-ray Observatory Satellite, Exosat, could re-enter the Earth's atmosphere during May unless engineers extend its planned period of operation by using on-board hydrazine thrusters to modify the orbit.

When launched in May 1983, Exosat had a planned operational life of two years and its chosen orbit meant it would re-enter the atmosphere approximately three years after launch.

On February 19, 1986 it completed 1000 days of in-orbit operation and during this time has made over 2000 observations of cosmic X-ray sources covering the complete range of celestial objects from the very familiar planets and stars we see in the night sky to such mysterious objects as quasars, neutron stars, black holes, supernova remnants, active galactic nuclei and clusters of galaxies.

The observations have been carried out from the European Space Operations Centre (ESOC) in Germany and have formed a rich data base that will provide a source of research for many years to come.

ULYSSES MUST WAIT

Prior to the tragic accident which occurred on January 28, Ulysses was scheduled for launch by the Space Shuttle on May 15, 1986. After consultation with the ESA Director General, Professor Reimar Lüst, NASA has now formally announced that it has postponed this mission. A new launch date will be decided upon by NASA after a schedule for resumption of Shuttle launches has been established.

Ulysses is a unique mission in that it will be the first spacecraft to study the poles of the Sun out of the ecliptic plane in which the planets orbit around our star. It was scheduled for launch on Challenger, and a NASA mission, Galileo, a planetary mission to Jupiter, was due to be launched by Atlantis five days later, on May 20.

Because of their trajectory requirements, both Ulysses and Galileo are dependent on the relative position of Jupiter and the Earth at the time of launch; Jupiter must be almost directly on the opposite side of the Sun from the Earth. This geometric arrangement occurs once every thirteen months. Therefore, for a direct launch to Jupiter, both missions would be delayed at least thirteen months until another launch window occurs. The Ulysses spacecraft and its scientific payload recently underwent successful final testing at Kennedy Space Centre, Florida. It will be placed in storage in anticipation of a launch which could be between June 22 and July 14, 1987.

FRENCHMEN TRAIN FOR MIR

France and the Soviet Union are finalising plans for a long duration flight of a French national on the new Soviet Space Station during the next two years.

The mission, at present planned for 1988, would last between six and seven weeks and is a follow-on to the Soyuz T-6 flight in 1982 when Jean Loup Chretien visited Salyut 7.

CNES, the French space agency, would conduct a number of scientific and biological experiments and is expected to offer the use of a new echo-cardiograph for gathering data on blood flow and performance of the heart during space flight.

The Soviet flight is also seen as an opportunity by France to experiment with equipment it ultimately plans to use on the Hermes mini-shuttle.

Divers Find Challenger Cabin

Engineers at NASA have been piecing together more clues to the Challenger explosion following the discovery of the Shuttle's crew compartment on the ocean floor.

First indications that the cabin had been located in 100 feet of water about 20 miles from Cape Canaveral came on March 7.

Relatives of the crew were informed immediately but it was several days before a public announcement of the find was made.

The search for wreckage has been going on since the explosion which destroyed Challenger shortly after launch on January 28. It has involved 11 ships and two small unmanned submarines operating across 350 spare miles of the ocean.

Meanwhile, as the Presidential Commission continues its inquiry, NASA has set up a "Headquarters Re-planning Task Force" to study alternatives for the future and evaluate the role that expendable boosters could play in replacing the Shuttle as primary satellite carriers.

As well as reviewing the requirements for a replacement Orbiter, currently estimated at costing £200,000 million, the task force is also considering:

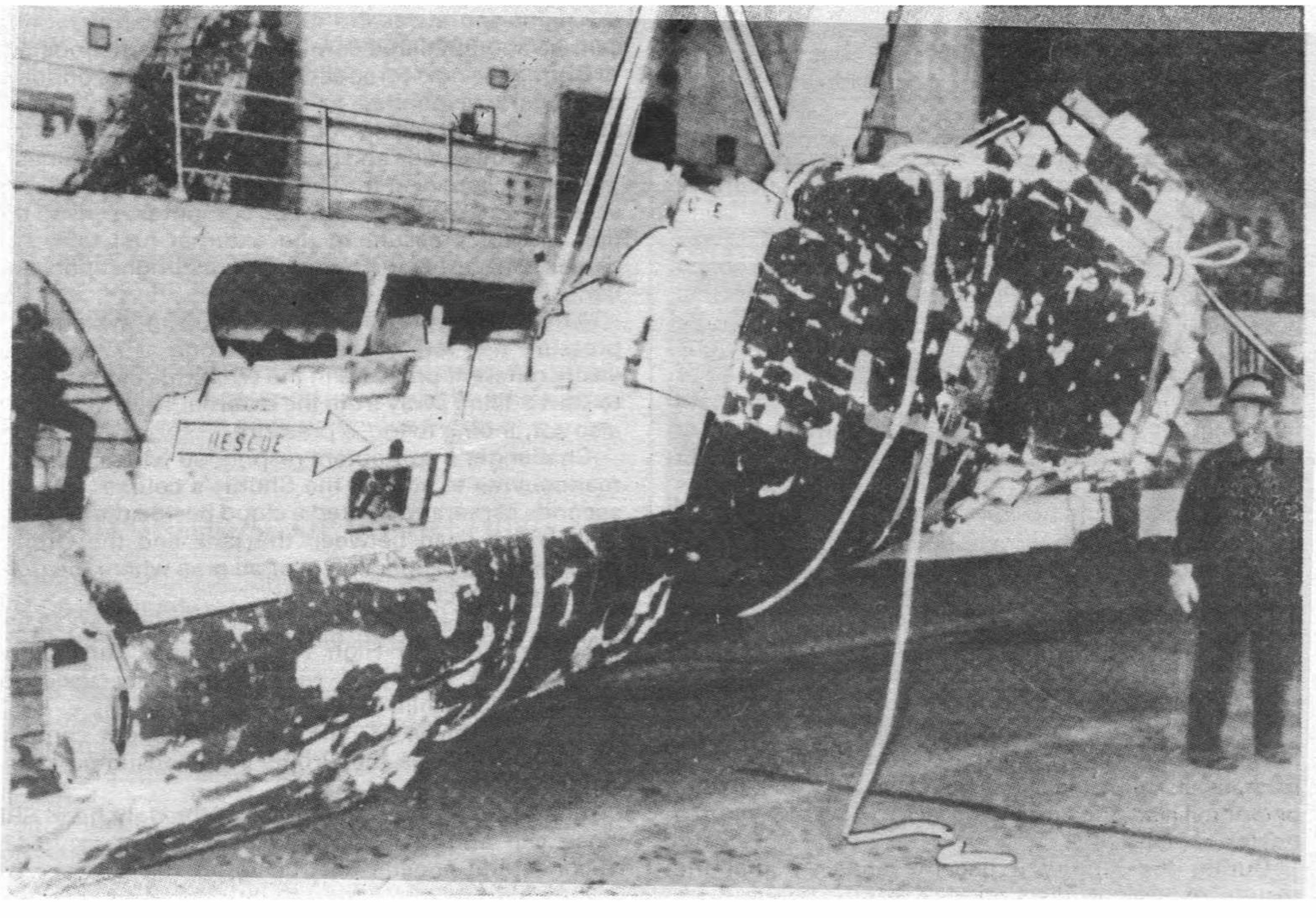
- Producing a new launch schedule for the remaining Shuttle fleet supplemented by expendable launch vehicles.
- Bringing the Vandenberg launch site "on line" and assigning a Shuttle there for several weeks to aid the process.
- Retaining ground communications stations which were to have been phased out with expansion of the Tracking Data and Relay Satellite System. A TDRS satellite was lost in the Challenger explosion.

President Regan is also expected to ask Congress for emergency funds to replace Challenger with a new Orbiter within the near future.

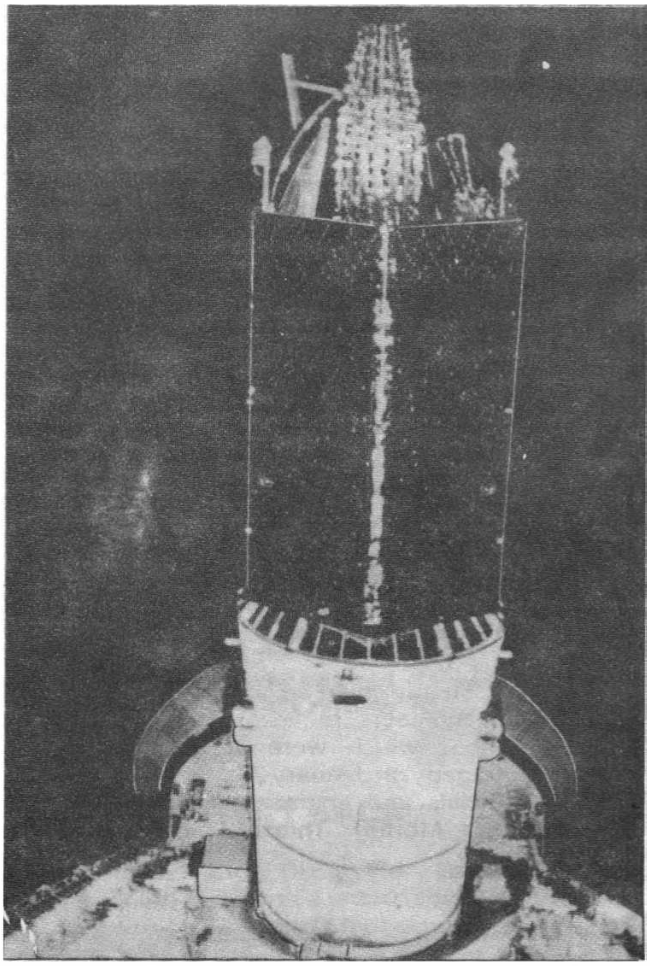
The Space Shuttle could be grounded for up to two years while engineers re-design the Solid Rocket Booster O-rings which were at the root of the Challenger tragedy on January 28.

NASA officials and engineers from the booster manufacturer, Morton Thiokol, agree that the

Wreckage of the Shuttle Challenger being returned to dry land by a US salvage ship.



UP-DATE USA



The TDRS satellite and its Inertial Upper Stage ready for release on flight STS-6. A similar satellite was lost in the Challenger explosion.

explosion was triggered by a rupture in the booster casing joint when the seals, which are adversely affected by cold weather, failed.

The launch site temperature for mission 51L was only 38 degrees Farenheit, by far the coolest conditions ever for a Shuttle launch. The next lowest temperature recorded at the time of a launch was some 13 degrees warmer and occurred on the previous flight, mission 61C on January 12.

The Presidential Commission set up to investigate the accident has been told that 15 engineers from Morton Thiokol raised serious concern over the effect of such low temperatures on the Solid Rocket Boosters (SRBs), prior to launch. They petitioned the company's senior representative at Kennedy Space Center, Allan McDonald, to disapprove of the launch.

As a result McDonald refused to sign the mission 51L flight readiness statement. Inquiry board members were told that this was the only occasion during the Shuttle programme such a recommendation not to fly had been made.

However, these launch objections were over-ruled by Joe Kilminster, Morton Thiokol vice-president, from his base at Thiokol facilities near Salt Lake City. NASA personnel also questioned the lack of data to support a postponement.

During the inquiry it became apparent that the results of various discussions were not passed on through the NASA chain of command for review at the highest levels. Key NASA managers involved in launch decisions were not informed of the serious flight safety considerations that were raised in the 24 hours prior to launch.

The inquiry board has also released a detailed account of what happened after Challenger lifted off from Pad 39B. The timeline was part of a presentation to the Presidential Commission on its visit to Kennedy Space Center during an early part of the inquiry.

The account starts with the ignition of Challenger's main engines 6.6 seconds before lift-off. At launch the SRBs ignited normally and the Shuttle's first movement off the pad occurred at 0.0587 seconds.

A puff of black smoke was detected between the right hand SRB and the External Tank as early as 0.445 seconds. This was the first indication that something was wrong.

By 2.147 seconds the black smoke extended halfway across the booster. Cameras continued to detect the smoke through tower clear, the roll manoeuvre, and as late at 12 or 13 seconds into the flight.

The mission then appeared to be functioning normally until 58.774 seconds into the flight when there was evidence of smoke from the side of the right SRB forward at the lower External Tank attach ring.

At this stage the Shuttle main engines had throttled up to 104 per cent thrust and the Orbiter was in its period of maximumn dynamic pressure. A second later the tracking cameras detected a well-defined plume of smoke.

Onboard computers sensed a difference in pressure between the right and left SRBs at 60.164 seconds into the flight and a fraction of a second later a tracking camera spotted flame coming from the right booster.

During the next three seconds Challenger's onboard computers responded to a change in the Shuttle's flight path by making minor adjustments to control panels on the wings and by moving the main engines.

A bright spot near the Orbiter was detected at 66.174 seconds and at 66.484 seconds computers sensed the first loss of pressure in the external fuel tank and cameras recorded the merging of the bright spots and flame.

AT 67.684 seconds the main propulsion system inlet pressure rise rate decreased. Starting at 72 seconds vastly different pressure in the two SRBs caused them to start pulling away from the External Tank which was also continuing to loose pressure.

Challenger's computers responded with a series of manoeuvres to correct the Shuttle's course. After 73 seconds cameras detected a cloud beside the external tank and a flash between the tank and the Orbiter followed by an explosion near an area where the right booster is attached to the tank.

Main engine number one shut down at 73.534 seconds after the High Pressure Fuel Turbopump became too hot, and rockets normally used for manoeuvring while in orbit began firing.

The final piece of data from Challenger came at 73.605 seconds as the Orbiter was consumed in the explosion

Cameras recorded separation of the right hand SRB nose cap and drogue chute deployment at 76.425 seconds and booster destruction at 109.604 seconds (right) and 110.266 seconds (left) by ground control.

NEW ORBITER NEEDED

NASA faces a launch crisis over the coming years even if Congress agrees to press ahead with construction of a replacement Orbiter for Challenger.

By 1990 it is predicted that Challenger's destruction will have resulted in the loss of 24 flights and without a replacement that figure is likely to increase at the rate of six per year thereafter.

If the Shuttle is only grounded for six months the near-term effect on launch schedules would be minimal, although in the longer term backlogged launches would be building up. Should the Shuttle be out of action for up to two years, a distinct possibility if major re-design work is undertaken on the boosters, the situation will worsen considerably.

The backlog would soon rise to 30 flights and with military flights taking priority NASA missions would be further delayed. The result of a full two year slippage would mean the postponement of 35 missions and the Department of Defense would find itself lumbered with 21 high priority payloads.

The alternative to Shuttle of expendable launch vehicles (ELVs) is also being examined as a means of relieving the launch crisis but it would still take two years for the production of eight Delta launch vehicles from the point of initial go ahead.

Amongthe other ELV options being considered are to increase the number of Titan 34D-7's available beyond the present plan for 10. These are capable of launching payloads of a similar size and shape to those put into orbit by the Shuttle.

Other options include continued modification of the retired Titan 2 ICBM beyond the planned 13 and the continued launching of existing ELV's like the Atlas and Titan 34D.

William Graham, NASA's acting administrator, believes that a three Orbiter fleet reactivated within a year would achieve launch rates of nine during the first 12 months, 14 in the second and up to 18 in third 12 months.

It seems increasingly likely that any delay in the construction of a fifth Orbiter (which could take approximately three and a half years) would seriously impinge on NASA's Space Station plans.

The Station's assembly would require 12 to 18 dedicated Shuttle flights and once built, by 1994 under current plans, would need up to nine flights a year for servicing.

YOUNG CRITICAL OF LAUNCHING

Veteran astronaut John Young, commander of the first Space Shuttle mission, has claimed NASA "risked lives" to avoid falling behind on a crowded launch schedule.

In a strongly worded memo dated March 4 Young, chief of NASA's astronaut office, delivered a harsh attack on the agency.

The 12 page memo warned: "If the management system is not big enough to stop the Shuttle programme whenever necessary to make flight safety corrections it will not survive and neither will our three Space Shuttles or their flight crews."

He spoke of the increasing pressure to launch NASA had been under for mission 51L even after experts had given various warnings and called for a postponement.

"We have already launched with less than certain full reliability and full redundancy of the systems," he stated.

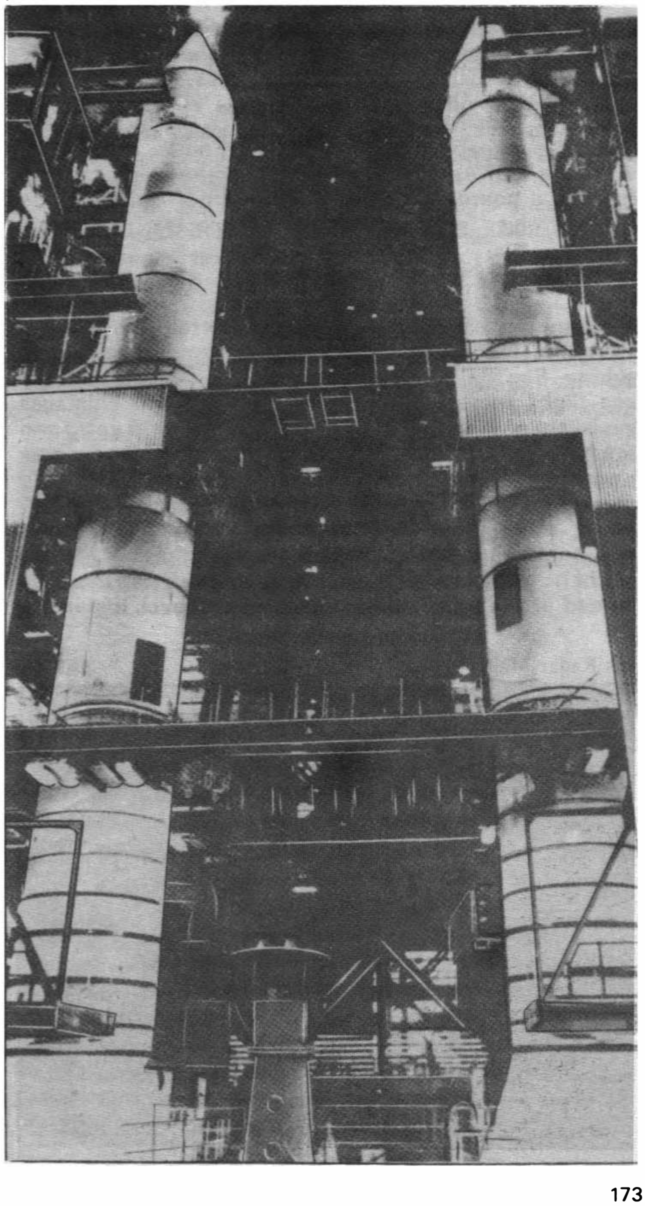
"We should not allow any increase in the inherent risk of operating the Space Shuttle just to increase the launch rate, reduce operating costs, or fly unsafe payloads."

Detailing what he termed an "awesome list" of safety problems that threatened astronauts' lives, Young claimed that NASA had relegated safety to a back seat on several occasions.

Astronaut Dr Sally Ride, a member of the Presidential Commission, has publically stated that she is not yet ready to fly again in the Shuttle.

In response to the criticism from astronauts NASA has reiterated its intention not to launch the Shuttle again until all safety related issues have been properly addressed.

Investigation work is continuing on the SRBs seen here stacked in the Vehicle Assembly Building before mating with the Shuttle for an earlier mission



UP-DATE USA

Notebook From The Cape

by Gordon L. Harris

President Reagan's FY 1987 budget includes $7,641,347,000 for NASA, a slight increase over the FY '86 total of $7,587,203,000. This does not include the cut of 4.3 per cent directed by a new Balanced Budget and Emergency Control Act, another $28 million slice this year caused by termination of the Advanced Communications Technology Satellite, or the impact of the January 28 tragedy which reduced the Shuttle fleet to three vehicles.

There is a new item of $45 million for "transatmos-pheric research and technology" to develop a winged craft powered by ramjet, capable of taking off horizontally, reaching low orbit, and returning to Earth at will – two hours New York to Tokyo, Reagan said. This is considered a likely successor to the Shuttle.

★ ★ ★

The current television commentators unfamiliar with the U.S. Space programme's history and unwilling to learn something about it, reacted hysterically on February 15 when William Rogers, chariman of the presidential commission, asked the acting NASA administrator to remove certain personnel from the investigating activity.

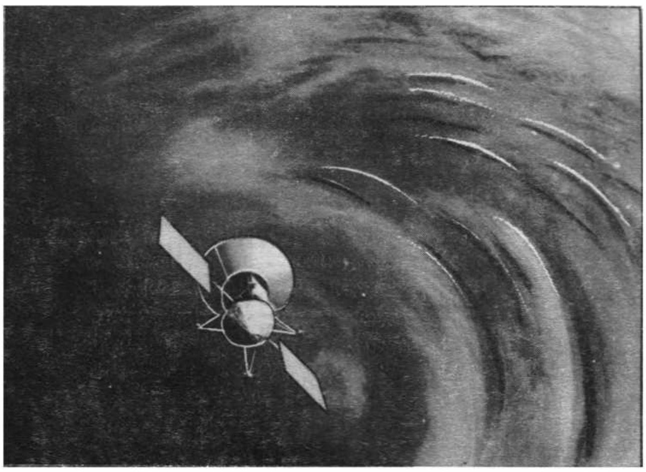
Rogers said that since the January 28 decision to launch "may have been flawed," those involved in the decision-making process should not investigate themselves. While Rogers did not name individuals, this was taken to mean the directors of Kennedy and Marshall Space Centers plus the programme manager at Johnson Space Center.

After the 1967 Apollo fire the administrator, James Webb, appointed a board of inquiry which did not include those actively involved in the test when the spacecraft burned.

★ ★ ★

Washington news bureaux also reported February 15 that Acting NASA Administrator Graham issued orders requiring Shuttle programme managers at the manned space flight center to report directly to him. This was reminiscent of Webb's action following the fire 19 years ago when he gave Boeing a special contract to look into the way the agency managed Apollo. It became infamous in the field centers as the Boeing TIE (technical integration effort) because other major contractors would not open their books to Boeing. When the effort was finished, Webb thought he had a modified system that would keep him fully informed at the programme management level, instead of through his field center directors. Men like Wernher von Braun, Kurt Debus and Robert Gilruth did not appreciate the implications of such an arrangement.

Venus Radar Mapper.



★ ★ ★

Five unmanned launches are currently scheduled this year. A NOAA GOES-G weather satellite will be flown on Delta, May 1. A Navy navigation satellite will be launched by Atlas Centaur during the summer. Another defence payload will be launched by Delta August 18. NOAA will sponsor a second launch October 9 of GOES-H aboard Delta. Navy will sanction a second navigation satellite mission aboard Atlas Centaur November 6.

★ ★ ★

The Aerospace Safety Advisory Panel warned in January 1985 that extra precautions were necessary because of the stepped-up pace of Shuttle launches. "The standard set during the first 15 safe and successful missions is admirable and commendable," the group wrote. "To maintain or improve on those standards will require exceptionally perceptive management and disciplined execution of the programme."

The panel was created in 1967 following the Apollo 1 fire which killed Astronauts Virgil Grissom, Roger Chaffee and Edward White. The Hartford, Conn, Courant reported February 8 that Shuttle inspections formerly conducted by full time inspectors are now performed by the workers themselves. As many as 18,000 fewer inspections are routinely performed on Shuttles because of changed NASA policy.

★ ★ ★

The Presidential Commission investigating Challenger's unexpected end arrived at the launch base February 13, for closed hearings of witnesses involved in NASA's probe. The group held a public session in Washington February 11, because of press reports that a NASA budget analyst had warned, in July 1985, that O-ring seals on SRBs might lead to a catastrophic failure. Chairman William Rogers, lawyer and once Secretary of State, handled the witnesses like a prosecutor as if to defend the space agency against its employee. Richard Cook held his ground and said he was leaving NASA for a more desirable job with the Treasury. His superior recalled the warning memo, said he talked to his superiors about it, and all hands were inclined to dismiss it because Cook was not an engineer.

Appointed Feburary 3, the commission also includes Neil Armstrong, deputy chairman, now chairman of Computing Technologies for Aviation, Inc. of Charloettesville, Virgina. He is also a member of the National Commission on Space and the Apollo veteran who walked on the moon.

Brig. Gen. Charles Yeager, retired, broke the sound barrier and was the first pilot to exceed 1,600 miles per hour in December 1953. He is also a member of the National Space Commission. Dr. Sally Ride, first U.S. woman in space, flew on STS-7 June 18, 1983. She is a physicist and mission specialist. Dr. Albert Wheelon, another physicist, is a vice president of Hughes Aircraft. Robert Rummel, formerly a TWA vice president, heads the firm of Rummel Associates of Mesa, Arizona.

Dr. Arthur Walker, Jr. is a Stanford University professor of applied physics. Richard Feynman is professor of theoretical physics at California Institute of Technology and won a

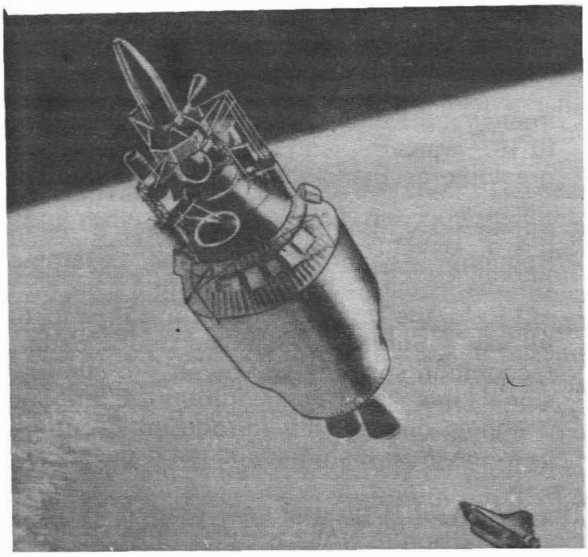
UP-DATE USA

Nobel prize in 1965. Eugene Covert is aeronautics professor at Massachusetts Institute of Technology and consultant to NASA on rocket engines. Robert B. Hotz is the retired editor of Aviation Week and Space Technology. David C. Acheson is a Washington attorney who was formerly vice president of Communications Satellite Corp. Maj. Gen. Donald Kutyna directs space systems, command control and communications for the U.S. Air Force.

★ ★ ★

The engineer in charge of SRBs at Marshall Space Flight Center, Lawrence Mulloy, said that if O-rings used to seal booster segments are found to have caused the mishap it could take from four months to three years to develop another solution or replacement.

★ ★ ★



An artist's impresison of the Galileo probe to Jupiter. It has now been delayed for at least 12 months.

The retired Army commander who managed the von Braun team when America's space programme was in its infancy believes the nation invited disasters by turning over too much responsibility to aerospace and armaments industries. Major General J. Bruce Medaris, now a priest of the Anglican Catholic church, said the government had lost competence to inspect, control quality and ensure safety and reliability among thousands of suppliers like those working with NASA.

The major change in policy occurred in the early 1960s under the Kennedy administration when the Defence Department abolished Army's arsenal system, becoming wholly dependent upon private industry. That change did not immediately affect the Medaris-von Braun team which joined forces in 1955. Medaris retired in 1960 after President Dwight Eisenhower decided to turn von Braun and Co. over to the NASA set up in 1958.

★ ★ ★

Air Force Lt. Col. Robert Nicholson said the range safety officer, an Air Force member, had no discretion when he blew off nose covers of Challenger's solid rocket boosters. Both strayed beyond the pre-determined flight path which made their destruction mandatory although at the instant neither threatened any populated area.

★ ★ ★

The Presidential Commission investigating Challenger's fiery end began hearings February 6, in the National Academy of Sciences. NASA witnesses briefed members on the agency's manned flight organisation, Shuttle design, construction and operations. The interim inquiry begun by Associate Administrator Jesse Moore will continue as an arm of the commission. Dr. William Graham, acting administrator, did not appoint the formal Board of Inquiry suggested by Moore immediately after the disaster. Congress may or may not follow the Commisison with another probe. Reagan gave Chairman William Rogers, deputy Chairman Neil Armstrong and the other commissioners 120 days to complete the job.

★ ★ ★

NASA's consistent, even monotonous claim that it would never risk astronaut lives – repeated by its political supporters including two members of Congress who flew as Shuttle passengers, came into sharp prominence during the Presidential Commission's investigation of Challenger's last, short flight.

The New York Times of February 9 quoted internal NASA memoranda warning that problems with O-ring seals employed at SRB mating could result in catastrophe, loss of mission, vehicle and crew. One such memo was dated in July 1985. Seventeen charred O-rings had been recovered with SRB cases after flight, suggesting that the plastic material was badly damaged by fire and pressure when the solid fuel ignited. The commission immediately called upon the agency to produce all such records.

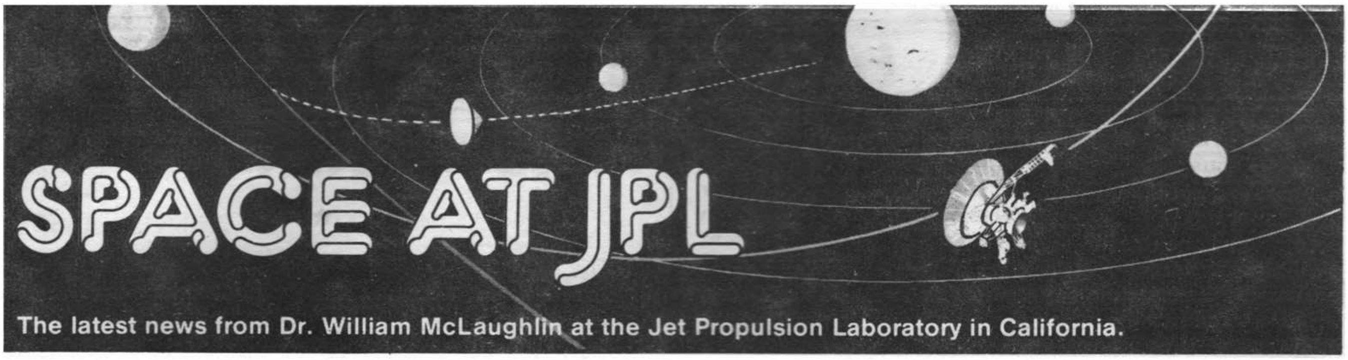
Whatever the outcome, the agency's record of 55 manned flights in 25 years came to a sudden halt January 28 with the worst space disaster of all time.

★ ★ ★

NASA has renamed two planetary missions which were supposed to fly in 1988 and 1990. A mission to map Venus, previously called Venus Radio Mapper, is now known as Magellan. The Mars Geoscience/Climatology Orbiter is now Mars Observer. Magellan will map Venus with a synthetic aperture radar instrument with subkilometre resolution. The spacecraft would orbit the planet every three hours as near as 250 kilometres from the surface. Mars Observer will map the planet to determine global elemental and minerological features and will record the Martian climate.

★ ★ ★

Dr. William Graham, acting administrator, relieved Philip Culbertson of his duties as NASA general manager February 16. Culbertson had held the post about two months, responsible for day-to-day operations. He will continue to work on long range planning. Charles Redmond, agency spokesman, said Dr. Graham indicated that given the conditions that followed the Challenger accident, what he called two-tiered management was cumbersom and he felt by taking direct control it would be more responsive to conditions. That change was followed up February 20, by announcement that Jesse Moore, associate administrator in charge of the Shuttle programme, would become chief of Johnson Space Center immediately. And former astronaut Richard Truly, a Navy rear admiral, returned as Moore's replacement. William Rogers, head of the President's investigating commission, called Moore's job change satisfactory because it removed him from control of the internal investigation of Challenger's loss.



Ploughmen to the Search

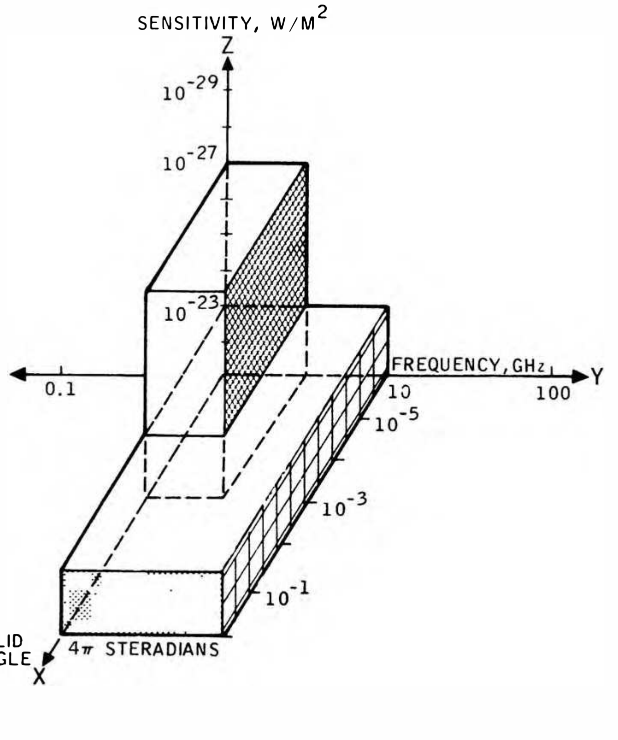
Since Frank Drake's pioneering Project Ozma, numerous attempts have been undertaken in the Search for Extraterestrial Intelligence (SETI), from spur-of-the-moment glances to systematic searches, and now a NASA SETI programme has been initiated with the intent of providing a wide-ranging search, yet one that is bounded in time, ending with the completion of a planned series of observations.

The systematic search started with Drake's Project Ozma. During May, June and July 1960, Drake employed a 26 m radio telescope at the National Radio Astronomy Observatory to examine the nearby, Sun-like stars Tau Ceti and Epsilon Eridani for signals of intelligent origin. The search concentrated near the 21 cm hydrogen line, which is favoured in SETI lore as a search frequency. For a tabular recapitulation of SETI efforts see [1].

The new search that is now being designed has strength in five key areas:

1. Area coverage: the whole sky will be searched.

The "SETI Cosmic Haystack" illustrates some of the properties of the two planned searches in the NASA SETI Programme: the All-Sky Survey and the Targeted Survey. The former covers the entire sky in a broad range of microwave frequencies. The latter looks at reduced ranges for spatial and frequency coverage but investigates stellar systems of interest using high sensitivity. NASA



2. Selectivity: although the whole sky will be observed, Sun-like stars within about 75 light years will independently be examined as part of a targeted search.

3. Frequency range: the search will cover a very large frequency range, 1 to 10 GHz (3 to 30 cm) for the All-Sky Survey, 1 to 3 GHz for the Targeted Survey.

4. Intensity: the entire sky will be observed down to 10^{-23} watts/m^2, with the selected portions of great interest being observed to 10^{-27} watts/m^2.

5. Signal resolution and complexity: 8 million frequency channels will be examined simultaneously, each one having a bandwidth of 1 Hz for the Targeted Survey and 32 Hz for the All-Sky Survey. Sophisticated pattern-recognition software will be able to identify a signal that is drifting through contiguous channels due to shift introduced by motion between the transmitter and the receiver.

The NASA SETI programme, funded by the Life Sciences Division of NASA's Office of Space Science and Applications, began in 1983 with a five-year initial preparatory phase. The goal of the programme is to carry out the dual-mode strategy (targeted and All-Sky) in the 10 years from 1988 and 1998. The necessary instrumentation will be built between 1988 and 1992; and the last six years will be occupied with heavy observing.

The plan is to use *existing* radio telescopes. The giant Arecibo dish and a 64m southern hemisphere radio telescope would support the Targeted Survey of individual stellar systems, primarily stars of spectral classes F, G, and K (the Sun is spectral class G), and 34m antennae of JPL's Deep Space Network would be used for the All-Sky Survey.

The Targeted Survey would spend between 100 and 1000 seconds observing each star, taking an independent spectrum once per second. The All-Sky Survey requires about 10 hours per day of observing time in order to complete the programme in 10 years. Of this time eight hours would be spent on the search and two hours for set-up time and re-examination of possible detections obtained during the day's search.

For the All-Sky Survey the antenna beam will be swept back and forth across the sky in a boustrophedonic pattern as in ploughing! Consecutive scans are to be separated slightly less than the half-power beam width of the radio telescope, to aid in the

detection of enduring signals. An interesting question arises as to what power to set as the level (threshold) at which a possible signal is re-examined. If that level is set too high, the sensitivity of the survey would be adversely affected. If that level is set too low, the system would be flooded with "detections" (false alarms) caused by noise and there would not be enough time to re-examine all of them. Hence, the threshold will be set so that statistically one can expect to have only about five false alarms per observing session to look at again; this number is manageable.

The SETI Program Office is located at NASA's Ames Research Center. The programme manager is Dr. Bernard Oliver, who has long been a driving force behind the theory and practice of SETI. The deputy is Dr. Michael Klein of JPL, whose recent book on SETI was reviewed in the May 1985 edition of this column. The Targeted Survey is the responsibility of the Ames Research centre, while JPL will conduct the All-Sky Survey. Dr. Samuel Gulkis is the project scientist for the All-Sky Survey.

There are numerous facts and streams of thought that have led to the present NASA SETI programme, but a few major influences can be distinguished. After the Project Cyclops study in the early 1970's, which envisaged an array of 100 antennae or more, each of 100m diameter, SETI thinking turned towards "doing it with silicon rather than concrete and steel". The use of existing radio telescopes and the construction of efficient spectrum analysers was felt to be a better approach for an early search than the construction of large, new radio-telescope facilities.

This type of thinking was brought to the forefront in a series of workshops held at the Ames Research Center in the mid 1970s.The resulting report [2] is a fundamental SETI document. Informal discussions at JPL among Bruce Murray, Sam Gulkis, Dick Goldstein, Bob Edelson and others reached the conclusion that the Laboratory could best contribute to SETI by applying its expertise to build large digital spectrum analysers and through utilisation of the Deep Space Network. Neither type of facility would be easily available to private individuals.

A major boost for SETI came when the prestigious National Research Council Astronomy Survey Committee report (the commitee was chaired by Dr. George B. Field of the Harvard-Smithsonian Center for Astrophysics) recommended a modest level, long-term SETI programme that would be open to the general scientific community.

A second major impetus for SETI took place in 1983 when the International Astronomical Union (IAU) created Commission 51, to address the search for extraterrestrial life. With the formation of this body, a scientific forum for SETI now existed. In October 1983, the *SETI Science Working Group Report* [3] evoked a response from NASA, and the current programme became a reality.

Our gratitude is extended to Dr. Samuel Gulkis for discussions on the NASA programmes.

REFERENCES

[1] **The Planetary Report**, March/April 1983, p.19

[2] P. Morrison, J. Billingham and J. Wolfe (Eds.),**The Search for Extraterrestrial Intelligence**, NASA SP-419, 1977

[3] Frank Drake, John H. Wolfe and Charles L. Seeger, **SETI Science Working Group Report**, NASA Technical Paper 2244, 1983

Joint Plan for Saturn Orbiter

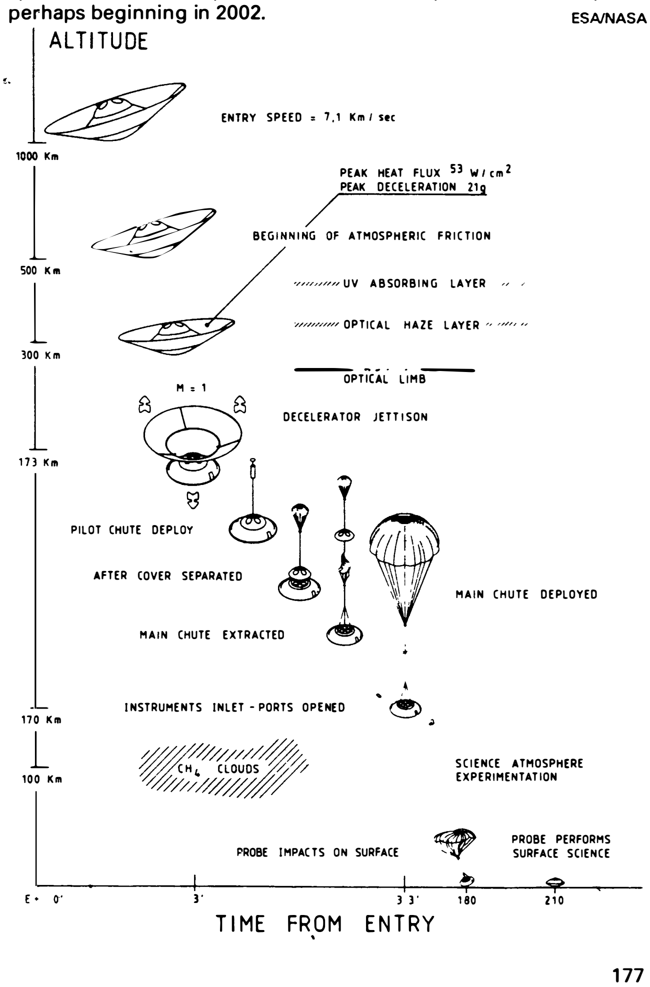
Comet Rendezvous Asteroid Flyby (CRAF) has been proposed as the first in a series of Mariner Mark II missions [1] and it is hoped that CRAF will be funded as a new project start for Fiscal Year 1988. Attention has already turned to the form of the second Mariner Mark II mission. Following the Galileo mission to Jupiter the next logical step would be a similar mission to Saturn.

A Saturn Orbiter/Titan Probe has been the subject of a recent ESA/NASA assessment study and may be the second Mariner Mark II mission. The proposal has been dubbed "Cassini" after the Italian-French astronomer Giovanni Cassini (1625-1712) who discovered four satellites of Saturn and the major division in its rings.

The basic mission scenario would begin with a Space Shuttle/Centaur G-prime launch in May 1994. The mass of the spacecraft relative to the launch-system capabilities precludes a direct flight to Saturn, so an Earth-gravity assist is planned (a so-called "delta-VEGA" manoeuvre, with "delta-V" representing the change in velocity and "EGA" an acronym for "Earth Gravity Assist", the source of the detla-V). The delta-VEGA is implemented by a three-year orbit around the Sun ending with a re-encounter with Earth, followed by a 4.5 year trip to Saturn.

Arriving at Saturn in January 2002, the spacecraft

The proposed ESA/NASA Cassini mission would release a probe into the atmosphere of Saturn's largest satellite Titan. An orbiting spacecraft would explore the Saturnian system for four years, perhaps beginning in 2002. ESA/NASA



would go into orbit about the planet with some help from a Titan gravity assist. After completion of the first orbit about Saturn, the Probe would be deployed into the atmosphere of Titan at 7 km/s. Probe data collected during its descent to the surface of the satellite would be relayed to Earth by the Orbiter. The Orbiter would continue to explore the Saturnian system for four years. The Probe would be built by ESA, the Orbiter by NASA.

Although Saturn has been explored to some extent by Pioneer 11 (1979), Voyager 1 (1980), and Voyager 2 (1981), these flyby missions have left many questions unanswered. The ESA/NASA assessment study lists scientific objectives in five categories: Titan, Saturn, rings, icy satellites, and magnetosphere of Saturn.

For example, a scientific objective with respect to Titan is to determine the nature and composition of the surface of this satellite, whose features are obscured by thick layers of aerosol. One model for the surface postulates hydrocarbon oceans, mostly of ethane, punctuated by a solid crust emerging in places from the ocean. A thick layer of organics, deposited from the atmosphere over geological periods, might cover the crustal upthrusts.

The actual structure of the surface could be investigated by both Orbiter and Probe with radar and infrared measurements from the former, visual and infrared observations from the latter. Several additional experiments can be considered if the Probe survives its landing on the surface and continues to transmit data to the Orbiter.

Another objective of Cassini ring studies is to investigate the interrelation of rings and satellites, including embedded satellites. The Voyager observations of the rings revealed an incredibly complex dynamical system. The narrow, "braided", F-ring is affected by two shepherding satellites, and several other nearby satellites have been proposed, but not observed, to account for F-ring dynamics. The presence of small satellites, or moonlets, has also been hypothesised, but not confirmed, within the main system of rings.

The solid-state imaging system of Cassini, with narrow-angle and wide-angle cameras, would allow a search for embedded moonlets as well as other aspects of ring structure such as correlations of ring morphology with the electromagnetic field.

Titan is the only satellite in the Saturnian system with enough mass to provide effective gravity assists for the Orbiter during its four year tour. Hence, Titan would be encountered more than 30 times in the tour: as an object of interest in itself and as a switching point, not only to the other satellites but also to desired points in the magnetosphere of Saturn.

Prior to encountering Saturn, Cassini would have two sojourns in the asteroid belt which would present excellent opportunities for encounters with asteroids. The first opportunity arises during the three year delta-VEGA loop. The large (114 km radius) asteroid Themis is a candidate for flyby in April 1996. The relative velocity at encounter would be a low 6 km/s. The second crossing of the asteroid belt, in the 4.5 year direct flight to Saturn after the Earth gravity assist, could feature a 16 km/s flyby of asteroid Viljev (10 km radius) in January 1998.

The structure of the Orbiter would be based upon the Voyager-type 10 bay, toroidal bus which provides a home for the electronics and a support for the high-gain antenna, RTG power source, Titan Probe, scan platform containing the remote sensing instruments, the fields and particles instrument turntable, etc.

Orbiter telecommunications would use X-band for uplink and downlink, and S-band and (possibly) K_a-Band for downlink. The X-band downlink data rate at Saturn would be somewhat over 19 kilobits per second.

Power would be supplied by radioisotope thermoelectric generators (RTGs) with 433 watts at launch, declining to 348 watts at the end of the mission.

The three-axis stablised spacecraft would employ a main engine with hydrazine bipropellants while hydrazine monopropollant is planned for attitude control to minimise contamination.

The dry mass of the Orbiter would be under 1500 kg.

The ESA Probe design features two major components: the high-speed deceleration system and the descent module. The deceleration system is used for braking during the entry phase of the mission in order to achieve subsonic speed high in the atmosphere of Titan so that atmospheric measurements can begin. The descent-module design employs a parachute. The total mass would be less than 200 kg for the probe.

The Galileo mission to Jupiter, scheduled for May 1986 launch, will follow-up the findings of Voyager and Pioneer with an intensive investigation of the giant planet. A logical next step in the exploration of the outer solar system would be to send Cassini to Saturn to perform a similar service. The mission would also continue the effective and enjoyable tradition of co-operation in space which has been growing between Europe and the United States in the last few years.

REFERENCE

[1] D. H. Collins and S. L. Miller, *JBIS*, 1986 (to be published)

Space Station Boosts Robotics

Artificial intelligence, robotics, teleoperation, expert systems, automation: these disciplines, and others, are emerging as the digital computer is being upgraded from the role of numerical device to that of assistant-to-humans. The Automation and Robotics Office at JPL is managed by Donna Pivirotto, who describes some of the activities in which her organisation is currently involved.

Two basic programmes are underway. The first seeks to develop the necessary core technology and the second will apply that technology to Space Station needs in the area of robotics.

The core-technology effort is being conducted not only at JPL but also at other NASA centres and in universities. Sub-disciplines include: sensing and perception (vision, touch, force); task planning and reasoning (artificial intelligence); operator interface (man-machine interface); control execution (mechanical); system architecture and integration. The concerted effort by NASA results from a congressional mandate to develop a plan for incorporating automation and robotics into Space Station and how to spin the technology off to industry. For Fiscal Year 1986 the sum of $5 million has been appropriated out of a total allocation of $205 million for Space Station.

An example of task planning and reasoning is the computer programme PLAN-IT, under development at the Laboratory. It builds upon previous experience with the construction of artificial intelligence tools (see "Space at JPL", ***Spaceflight***, April 1985). As the name indicates, the programme will provide planning capability, a capability which will feed into subsequent applications in robotics. PLAN-IT also supports systems autonomy work now in progress at the Ames Research center, an action which is reciprocated by technological support from Ames for the JPL robotics work.

The Greek root "tele" means "far off" or "at a distance" and is used in compounds such as "television" and "telemetry". Thus, the discipline of "telerobotics" can correctly be supposed to combine the autonomy associated with a robot with human control from afar. The goal is to introduce telerobotics into Space Station at the appropriate time, ie. when the technological maturity of the programme, as shown by the demonstrations, fits the needs of the Earth-orbit facility. The first phase of Space Station in-orbit assembly is scheduled for 1992 and the Laboratory's support of Space Station with telerobotics will be acomplished through demonstrations in 1987, 1990, 1993 and subsequent years.

What is a teleoperated robot in this context, and what functions could it be expected to perform?. It will have two arms, vision and not be equipped with superhuman reach or strength. The reason for the latter limitations is that a Space Station requirement states all work in orbit must be able to be done by humans, in case of problems with the automated system.

Naturally there will be much assembly work in conjunction with the establishment of Space Station, and a prime candidate for telerobotic tasks is thereby indicated. Robots would hold lights for labouring astronauts, hold tools, or, in more advanced modes, snap together pieces of the structure. Robots can also be taught to focus their vision systems upon a designated part or particular human, tracking it as it moves about and supplying a picture to a desired work station. One scenario for assembly features five people outside the facility, working along with the robots, and three people inside operating the telerobotics systems.

Initially, the telerobots will be designed with emphasis on "tele", the autonomy of the "robot" will grow as more and more capabilities are removed from the human and transferred to the machine.

Work by the Ames Researach center in systems autonomy will also be displayed in a series of demonstrations. The first two demonstrations are scheduled for 1988 and 1992 and will address the automation of portions of mission operations for the Shuttle: communications, station scheduling, fault diagnosis, etc.

Eventually, the system-autonomy effort could translate into Space Station support through supplying autonomous subsystems such as power and life support and protecting the station and crew through automatic fault protection algorithms.

The entire effort within NASA seems to promise a happy blend of the things that humans do best with the capabilities of smart machines, working together towards a common goal.

FUTURE MISSIONS

James R. French, a member of the technical staff in the Spacecraft Design and Engineering Section at JPL provides a summary of planned and possible future missions.

Missions firmly in the schedule beyond Galileo and ESA's Ulysses are an interesting mixture orientated towards astronomy, planetary exploration, and Earth observation. Before the Challenger disaster additional flights were planned of the Shuttle Imaging Radar (SIR), a synthetic aperture radar capable of high resolution imaging from the Space Shuttle. In addition TOPEX, a free-flying spacecraft, will use radar to study variations in the surface of the Earth's oceans to understand current flows, bottom profiles and other significant characteristics.

Turning away from Earth, 1988 will see the launch of Venus radar mapping mission Magellan, planned to obtain 1 km resolution mapping of 90 per cent of the surface of Venus using imaging radar techniques. In 1990 the Mars Observer will be launched towards a low polar orbit of Mars to conduct a detailed study of surface and atmospheric constituents and the interactions between them. This mission is of additional interest because it represents the first use of a spacecraft designed for Earth orbit to investigate another Solar System body. A possible later mission in this series would be a rendezvous with a near-Earth asteroid.

In the field of astronomy, JPL has a major role in the Hubble Space Telescope, contributing two major instruments in one package which will use the telescope optics. The Wider Field/Planetary Camera comprises the Wide Field Camera for survey and mapping and the Planetary Camera for very high resolution work studying planetary surfaces as well as other demanding tasks such as looking for the tiny wobble in the motion of distant stars which might indicate the presence of planets.

Missions as yet not approved include the Mariner Mk II series of highly flexible, adaptable spacecraft for a variety of outer Solar System missions. The first for this series would include rendezvous with a short period comet with flyby of one or more asteroids enroute. The second mission would be a Saturn orbiter carrying a probe to be dropped into the dense atmosphere of the satellite Titan.

More ambitious missions yet to be firmly scheduled include a large autonomous unmanned rover vehicle for Mars. Scientists would also like to have sample Martian materials returned to Earth for analysis and various approaches to this goal have been studied. The Mars Airplane operated as a remotely piloted vehicle was discussed as useful adjunct to a manned mission. Manufacturing of propellants for return to Earth from Martian resources would greatly reduce transport cost for support of a large Mars exploration. Finally, high energy, low thrust electric propulsion using a nuclear power source offers the possibility of missions not achievable by any other means. An example is a spacecraft which could hover above the rings of Saturn for close observation.

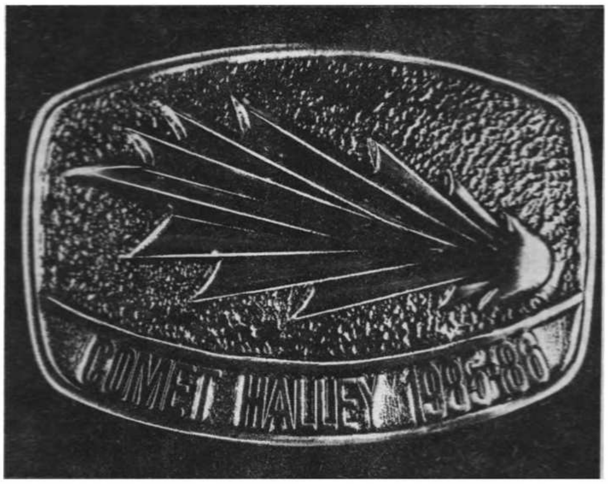
VINTAGE COMET

Among the more whimsical or romantic matters brought to light by current research related to comets (notably, of course, that of Edmund Halley) one of particular interest in the wine-producing areas of Europe, especially France, is the firmly established belief that a visiting comet will guarantee a good vintage for the year of the visit. This belief owes much to the fact that the passage of the great comet of 1811 (not Halley's) marked a year of quite exceptional vintage in both quality and quantity. So much so that there was a popular song in Paris cabarets around the end of last century which ran:

Each morning, after midnight
The Comet, rising high
Turned all the grapes to silver
With soft light from the sky;
Jealous of the Comet's work
The Sun gave warm, sweet days
Painting every laden vine
With pure gold from his rays.

Special bottles, bearing a moulded representation of a comet, were produced in substantial numbers (see page 370, September/October 1985 issue of *Spaceflight*). Ever since, the best champagne vintages have been bottled with a similar representation on their corks and/or their labels.

Unfortunately, reality does not confirm this relationship between heavenly visitors and heavenly vintages. For example, the last three returns of Halley's comet (1759, 1835 and 1910) were far from brilliant either for champagne or other wines, whereas there have been several "non-comet" years (the most recent 1983) when weather conditions similar to those of 1811 produced some very fine vintages indeed.



COMET BUCKLE

This Halley's comet item is a belt buckle on sale in the US and bought recently by Society Fellow Douglas Arnold. It is composed of "solid alloys finished in antique brass" and was created by Californian artist Michael West who based the design on the 684AD apparition of the comet, published in the Nuremberg Chronicle.

Nonetheless comet emblems have become established as indicating superb champagne, cognac and other vintages, and any reader of this note who is lucky enough to possess such a bottle might care to dedicate it to the BIS, for use according to ancient custom at next year's Halley celebrations. The empty bottle could then be preserved in the Society's museum.

Halley's comet photographed on January 10, 1986 at the Max Planck Institute for Astronomy, Heidelberg, Germany. Discontinuities in the tail can be clearly seen. *MPI*

GIOTTO SEES SOLAR FLARE

The Giotto probe has measured some dramatic effects caused by a burst of solar flares. One huge flare, very unusually coming up after solar minimum, was seen on February 6. By February 7, the shock wave in the solar wind caused by the flare reached the Earth causing disturbances to the magnetic field which were so great that the aurora was seen over southern England on the evening of February 8.

Meanwhile plasma experiments on Giotto were measuring the solar wind at a different part of the Solar System. At 0236 on February 8, a sudden increase was noted in the solar wind density, temperature and speed. An event like this is known as an interplanetary shock. Further events associated with the flare were seen on the two following evenings, including an increase in the helium content of the solar wind, a sudden drop in solar wind temperature, and other boundaries between different plasma regions. At one point the solar wind was travelling at the unusually high speed of 900 km/s (over 2 million miles per hour). The average speed is only 400 km/s.

Comparisons to be made over the next few months with other spacecraft nearer Earth should give information on the shape of this sudden and temporary protrusion of the Sun's atmosphere.

The aim of the MSSL-led Johnstone Plasma Analyser (JPA) experiment is to investigate the formation of the comet's ion tail. This is done by measuring both the ions from the solar wind which slow down and deflect around the comet and also the ions from the comet itself.

UPDATE ON BACKDATE

Although the earliest known recorded observation of Halley's comet was made by the Chinese in 240 BC, attempts have been made to determine its long-term motion back to 1404 BC by taking account of gravitational effects of other planets. [1].

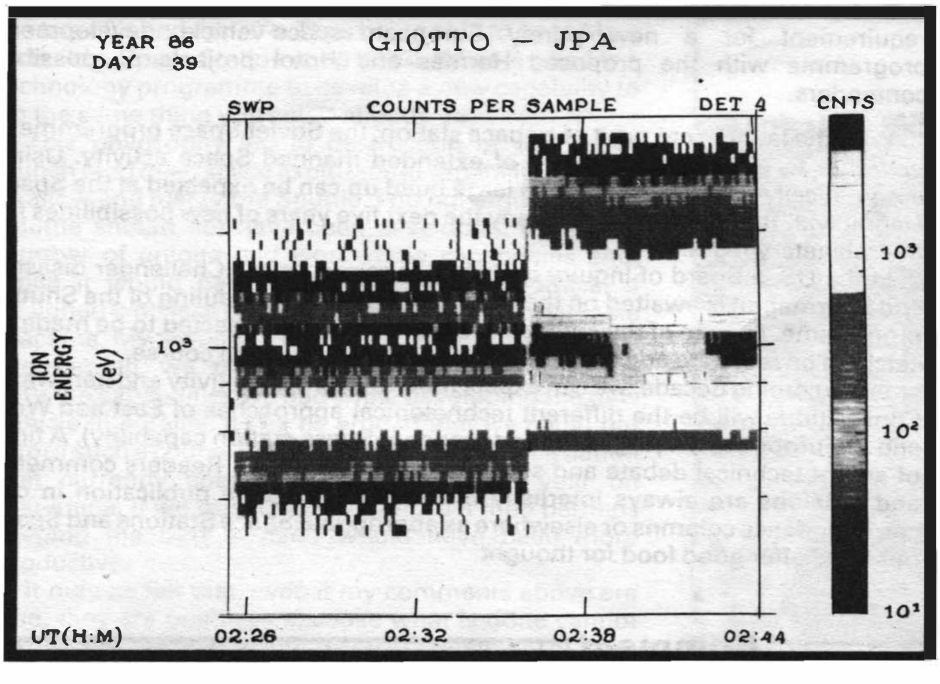
Generally, returns of the comet between 315 BC and 140 BC would have been hard to spot. Only two were really favourable (in 126 BC and 140 BC) with the latter seeing the comet pass the Earth within a distance of just 0.04 Astronomical Units (1AU = Earth, Sun distance).

The recent discovery of the Babylonian tablets recording the 164 BC return [2] and personal recollections of a Babylonian stele [3] of even earlier date invite speculation as to whether pre 240 BC observations of the comet really exist.

Apart from difficulties both in interpreting anything recorded and prolonged periods of cloudy weather, the 1985/6 return has shown how inconspicuous the comet can sometimes be, while the 1910 return amply illustrated the chances of more confusion with the appearance of the Great Daylight comet a few months before Halley. On the other hand, Halley's comet (now "middle-aged") would not have lost so much of its gases three thousand years ago.

References

[1] "The long-term motion of Halley's comet" by D. K. Yeomans and T. Kiang. Month, Not, R.A.S. Vol. 197 (1981) pp633-646.
[2] "Halley's comet and Babylon" by R. Stephenson, G. K. Yau. Spaceflight, Vol.27 (9-10) p.360.
[3] "From the Secretary's Desk" Spaceflight Vol.27 (9-10) p.370.



The Johnston Plasma Analyser (JPA) measures an interplanetary shock. The picture shows the detection of an interplanetary shock by the JPA instrument on ESA's Giotto spacecraft early in the morning on February 8, 1986.

In the plot 19 minutes of data from the Fast Ion sensor are shown. The solar wind distribution is measured once every 8 seconds. The vertical axis is energy/charge and the horizontal axis is time. The colours (here shown in black-and-white) represent numbers of counts detected at a particular energy, summed over all directions.

Before the shock two distinct peaks are visible. These are due to the solar wind protons (hydrogen ions, lower peak) and alpha particles (doubly charged helium ions, upper peak) which travel at almost the same speed. At the shock the energy of the distribution increases dramatically, corresponding to a speed increase from 370 to 430 km/s.

MSSL

SPACE STATIONS AND SPACE MISSIONS

Let us first recognise that putting a payload into orbit requires a massive propulsion system. Space launch vehicles look deceptively smaller on the TV screen than in real life! The case for optimising design could not be more overwhelming. So why do we not see the two Space superpowers doing the same Space spectaculars in the same way, both ideally optimised? The Space 'race', if that is what it is, has similarities with the athletics track. Competitors develop their own tactical approach according to their inherent strengths, immediate or long-term objectives and natural inclinations.

Soviet Space developments have been spectacular. The launching of the first Sputnik astounded the world as did the launch-vehicle capability that its size and weight implied. The event has since been repeated with larger payloads and larger implied launching capabilities. Automation and remote control first featured in Soviet lunar exploration and then in automatic docking in Earth orbit. The Soviet approach has centred round continuous evolutionary development of carefully selected basic technologies such as the two just mentioned to which may be added their system of land recovery by parachute and jet-braking. The evolutionary approach is commended by the many 'firsts' that it can claim particularly in the area of manned spaceflight, including the Space endurance record.

The US Space programme can be credited with Space spectaculars in the superlative. The Apollo lunar programme, which is now all but relegated to the history books, involved a whole range of new technologies for the manned exploration of an airless Moon. The US unmanned planetary programme has broken new technological ground in a different direction, whereas manned space flight has continued with Shuttle and Orbiter development and a whole range of new technologies, including those needed for the return of a winged vehicle from orbit to a runway on Earth. The US Space programme can be seen as a broad one in which radical conceptual changes have been accepted leading to a great variety of new in-space capabilities, spectacularly demonstrated.

With the approach of the 21st century, the major Space requirement will be for the transportation to orbit (generally to a space station) of large payloads, cheaply. Two types of Space transportation are foreseen. One is for an unmanned, unsophisticated cargo-carrying launch vehicle, which may be reusable (if the payload market is sufficiently large to justify the additional cost of reusability). The Shuttle clearly does not meet this requirement being manned, sophisticated and carrying to orbit only one quarter of the payload of a Saturn V.

The other type of vehicle will be for shuttling men and supplies between Earth and orbit. The Shuttle fulfills this role, but not cheaply. The Shuttle was designed for flexibility in its applications and not for cost optimisation. To illustrate the point, we have in the case of conventional aircraft, both experimental aircraft and operational aircraft. The Shuttle is the Space counterpart of the experimental aircraft, whereas what is needed is the Space counterpart of the operational aircraft. Europe is looking at this type of requirement for a new purely European space-vehicle development programme with the proposed Hermes and Hotol projects as possible contenders.

With the launch into orbit of a space station, the Soviet Space programme is now due to embark on a period of extended manned Space activity. Using automatically-docking satellites, a large build up can be expected at the Space station with the opening up, over say the next five years of new possibilities for interplanetary flight.

In the US, a Board of Inquiry is shortly to report on the Challenger disaster and information is awaited on the resumption and re-scheduling of the Shuttle programme. In spite of the setback every effort can be expected to be made to catch up on lost time and keep the Space Station project on course.

In the coming decade, we can expect mounting orbital activity and hardware. Conspicuous will be the different technological approaches of East and West and of Europe (now vying for an independent Space station capability). A time of ardent technical debate and soul-searching lies ahead. Readers comments and opinions are always interestly received for possible publication in our correpondence columns or elsewhere as appropriate.Space Stations and Space missions offer good food for thought.

New Missions Ousted By Technology Love

Sir, In reading "Space: the Long-Range Future" by Jesco von Puttkamer, (*Spaceflight* 1985, pages 348-354 and 395-400), I was struck by his quotation of a NASA study that what we really require for major space exploration efforts are: a heavy lift launch vehicle and a low cost means of transport to orbit. The reason that I find this striking is that we had these capabilities 15 years ago and discarded them.

The Saturn V had a demonstrated capability to place over 100,000 kg into low orbit and was potentially capable of a substantial upgrade. True, it was not reusable. However, it probably could have evolved toward partial reusability had we elected to apply the same heroic efforts to it that have gone into making the Shuttle SRB's "reusable". The magnificent Saturn now exists only in museums and the memory of those of us who helped develop it.

As for transport of personnel and smaller cargo, the Apollo/Saturn 1B combination with a cargo cannister riding below the Service Module could have delivered several persons and some cargo to a Space Station. An unmanned all-cargo version would also have been attractive for satellite launches and other cargo in the 25,000 to 30,000 kg range.

A Space Station comprising two second generation, refurbishable Skylabs docked end-to-end would have provided more volume than NASA's present concept will ever have. Further we would by now have eight to ten years of experience with long term operations in space rather than still waiting for the chance to begin such activities in perhaps another eight years.

To what malign influence can this waste of a tremendous capability be attributed? Simply to the characteristic of so many engineers and managers: the love of new technology. Space planning is dominated (in the US at least) by the spinoff mindset which implicitly states that space endeavours are not useful in themselves but only for the technology they generate. Such thinking seems to derive from the desperate efforts to justify space exploration in terms of frying pans and portable radios which characterised the late 60's and the 70's. Thus being able to go to Mars or build a Space Station is no good. What is good is a technology programme to develop a new capability to do the same thing you could already do.

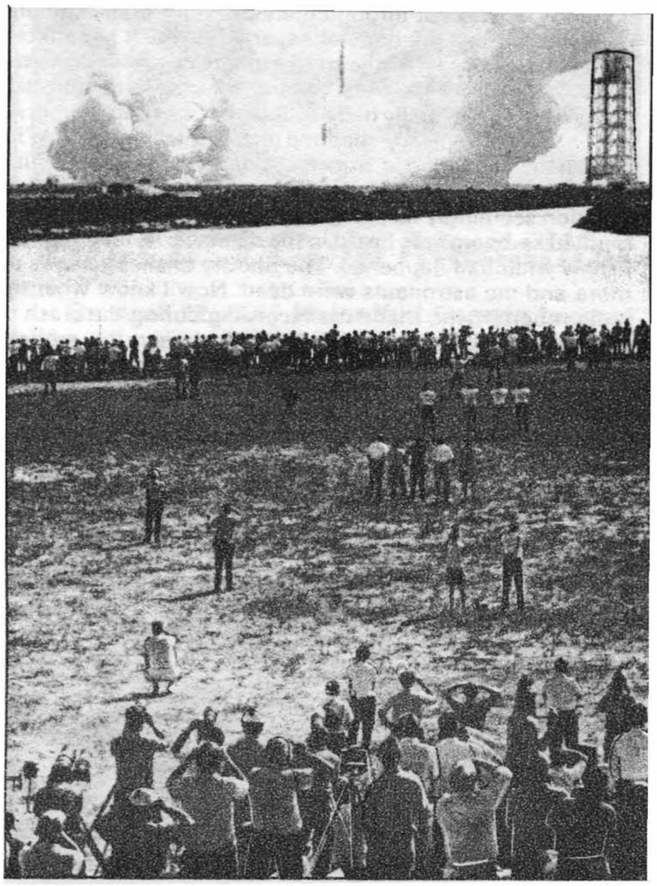
This philosophy led to destruction of our heavy launch (and deep space exploration) capability in order to allow and justify the Shuttle. I do not argue that the Shuttle should not have been developed. It offers a number of unique and worthwhile capabilities and, while it would have been far more economical if designed with less political help, it is still a remarkable machine. My argument is that, in a properly run space programme, we should have continued operations with the capabilities we had while developing the new vehicle in parallel. It will be argued that we could not afford such a course but that seems farcical for a nation that currently spends $1600 million per year on marijuana. If we truly could not afford it then perhaps keeping the bird in hand would have been more productive.

It may be felt that, even if my comments above are true, they are pointless because what is done cannot be undone. No one can argue the irreversibility of time, however, the study of history is worthwhile if we can learn from it. The point to be made here is that, since Apollo, there has been no focus upon doing missions. Instead effort is totally directed towards new development. This is a part of the reason why it would require 15 years to return to the Moon when it took only eight to go there the first time. Similarly, any mission to Mars will be far in the future because of the development that will be done whether it is really needed or not.

Like Arthur Clarke, I can think of no more appropriate celebration of the 500th anniversary of the voyage of Columbus than for a small fleet of spaceships to depart Earth en route to Mars. This is not impossible even starting now. But, I fear, it will remain only a dream stifled by unending planning efforts and studies which lead nowhere. We seem to be lacking an Isabella who will sell her jewels to back the expansion of human horizons; and we seem to be short of those with the spirit of Columbus to take the ships he found available and set forth rather than propose a new ship-building technology programme that might make it more comfortable to go exploring in the next century. We need Columbus' kind of vision far more than we need new technical breakthroughs.

J. R. FRENCH
California, USA

The Saturn V rocket, seen here in July 1969 at the launch of Apollo 11, demonstrated the capability of placing over 100,000 kg into low Earth orbit and was potentially capable of substantial upgrade.



CORRESPONDENCE

Recollections

Sir, I do not know how many of your readers witnessed the tragic Challenger accident from the Kennedy Space Center on January 28 but I thought I would send along some of my recollections of that day's events.

Having earlier toured the gargantuan flame trench and pad fixtures of the newly renovated Shuttle Launch Complex 39B at the Kennedy Space Center, I was anxious to see the first launch from the second Shuttle launch pad. The situation was better than I had hoped for – the Orbiter Challenger was fully visible from the press site and would provide the best ever view of a Shuttle launch. With launches from Pad 39A the presence of the Rotating Service Structure prevented viewers from seeing the vehicle until the tower was clear.

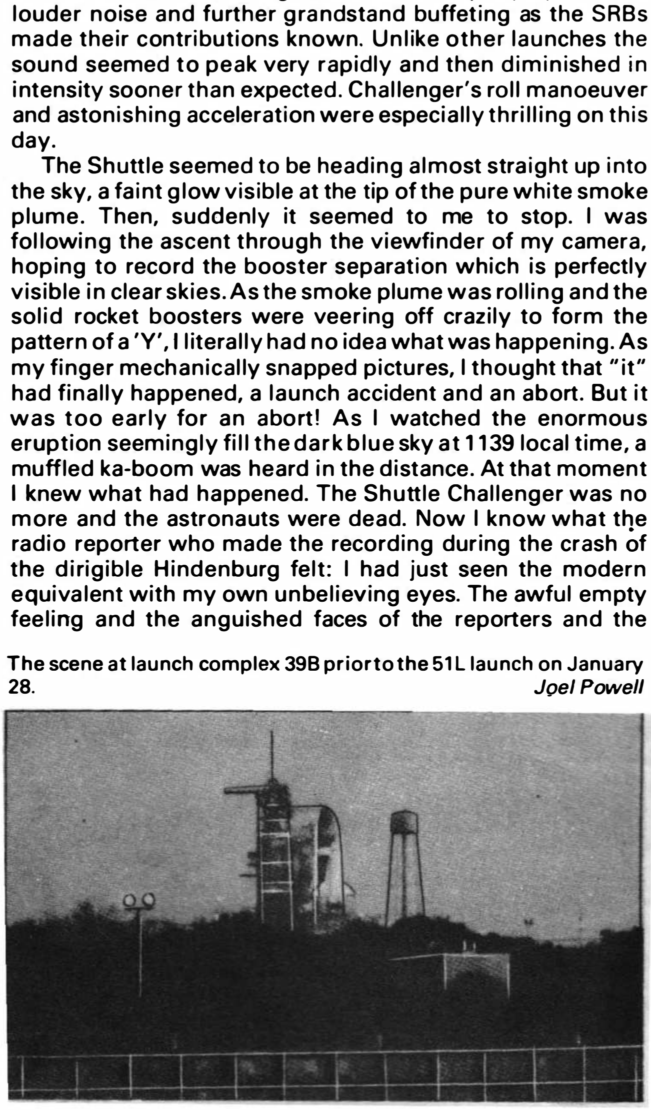
The chill Florida air had warmed slightly during the long two hour unplanned hold called to ensure that ice formation at the pad would not damage the fragile TPS tiles during liftoff. The familiar red glow (from TV) appeared under each Shuttle main engine at the T-6 second ignition time, and at T-0 Challenger rose off the pad on the distinctive twin pillars of flame from the SRBs. A sudden roar and the buffeting and rattling of the nearby press grandstand shattered the eerie silence of the launch (the pad is nearly five km distant after all, although it seemed to be closer than Pad 39A). This was the voice of the main engines, followed rapidly by an even louder noise and further grandstand buffeting as the SRBs made their contributions known. Unlike other launches the sound seemed to peak very rapidly and then diminished in intensity sooner than expected. Challenger's roll manoeuver and astonishing acceleration were especially thrilling on this day.

The Shuttle seemed to be heading almost straight up into the sky, a faint glow visible at the tip of the pure white smoke plume. Then, suddenly it seemed to me to stop. I was following the ascent through the viewfinder of my camera, hoping to record the booster separation which is perfectly visible in clear skies. As the smoke plume was rolling and the solid rocket boosters were veering off crazily to form the pattern of a 'Y', I literally had no idea what was happening. As my finger mechanically snapped pictures, I thought that "it" had finally happened, a launch accident and an abort. But it was too early for an abort! As I watched the enormous eruption seemingly fill the dark blue sky at 1139 local time, a muffled ka-boom was heard in the distance. At that moment I knew what had happened. The Shuttle Challenger was no more and the astronauts were dead. Now I know what the radio reporter who made the recording during the crash of the dirigible Hindenburg felt: I had just seen the modern equivalent with my own unbelieving eyes. The awful empty feeling and the anguished faces of the reporters and the lingering smoke cloud are something I will never forget. We were utterly helpless.

I think Steve Nessbit can be forgiven for his seemingly callous 'major malfunction' remark from Houston. Most of the reporters were out of sight of the TV monitors at the grandstand, and the launch and explosion scenes were not replayed (I had to wait until I arrived home late that evening before I saw those heart-rending replays). A few minutes later the SRB drogue parachute drifted out of the sky but that was all that was visible of the debris shower or the SRB destruction.

I don't know about you but the grief and the pain has turned to shock and anger as the incredible series of events leading to the disaster unfolds. It is going to be a very long year: shades of the Apollo 204 fire nineteen years-and-a-day ago...

The scene at launch complex 39B prior to the 51L launch on January 28. *Joel Powell*



JOEL POWELL
Calgary, Canada

March Issue

Sir, My congratulations to the editor of ***Spaceflight*** and everyone else involved with the March issue for the in-depth and thoughtful coverage of the Shuttle disaster. It must have involved considerable re-working of the issue at very short notice.

MIRIAM E. MASON
Redhill, Surrey

Sir, Just a few lines to say how much I enjoyed reading the March ***Spaceflight***. Several of the articles I anticipated in advance but your presentation was even better than I had expected. Congratulations on a magnificent magazine.

W. P. DILLON
Luton, Beds.

Ed. *Thank you kindly on behalf of everyone involved including the many BIS members who voluntarily provide the written contributions on which* ***Spaceflight*** *depends.*

Comet Port Wine

Sir, I quote from George F. Chambers' "The Story of The Comets", 2nd ed.(see 'Comet Wine' in *Spaceflight* 1986, Vol. 28, p.88) 1910 – "...The comet 1811 obtained in Western Europe and especially in Great Britain, fame of a very un-astronomical character. Its year of appearance was also the year of an unusually celebrated port wine vintage in Portugal, and the "Comet Wine" figured for a long period of years, first of all in the price lists of wine merchants, and afterwards in the cellar books of many private houses, and finally in the advertisements of auction sales. The last such advertisement which I remember to have seen appeared in the Times somewhere in the "Eighties", so the wine and the label thereof lasted long."

Sir Arthur Conan Doyle also appreciated this vintage, as he reveals in his story "The Stockbroker's Clerk". He causes Watson to observe – "...Then Sherlock Holmes cocked his eye at me, leaning back on the cushions with a pleased yet critical face, like a connoiseur who has just taken his first sip of a comet vintage".

It is possible that little of this vintage may still exist. I remember seeing, some years ago, port vintages in a strongroom in the Real Companhia Vinicola vinyards, which spanned years back to 1800. I cannot remember whether a comet vintage was included.

MAX WHOLEY
Midhurst, Sussex

40th ANNIVERSARY

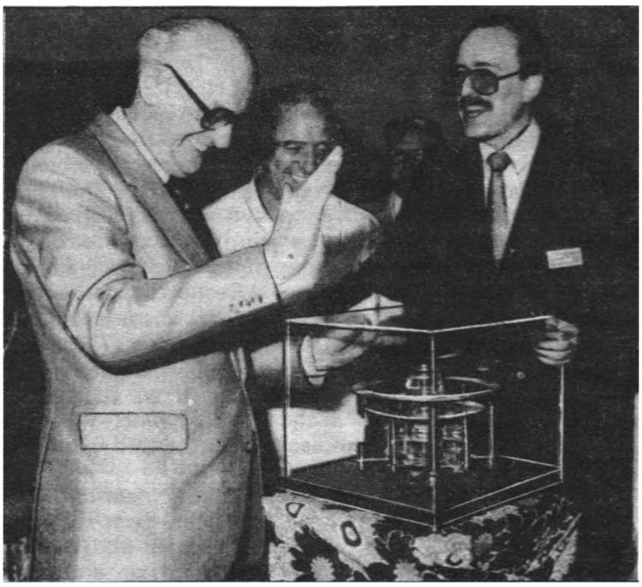
BIS Honorary Fellow Arthur C. Clarke, widely recognised as the "father" of satellite communications, has been presented by British Telecom with an Orrery clock. The presentation in Sri Lanka, where Mr. Clarke has lived for 30 years, was made by Mr. John Baker, Regional Director for British Telconsult, part of BTs newly-formed Overseas Division.

The clock is based on a model produced by George Graham in the early 1700s and copied by George Rowley, whose patron was the fourth Earl of Orrery. It shows the position of the Earth in relation to other planets.

The ceremony marked the 40th anniversary of the publication by Mr. Clarke of the principles of geostationary satellite communications and took place at an exhibition in Sri Lanka, where the Arthur C. Clarke Centre for Modern Technologies is based.

Presenting the clock Mr. Baker said: "Telecommunications are the infrastructure upon which the economic viability of nations depends. They turn the wheels of commerce and support our most vital social services. There are few people in the world today whose lives are not influenced in some way by satellite communications. By presenting this clock, British Telecom – as one of the world's major providers of international satellite communications – can in a small way pay tribute to the man who started it all."

Arthur C. Clarke (left) receives an Orrery clock from Mr. John Baker of British Telconsult. *Telecom Today*



GIOTTO ENCOUNTER

Our Executive Secretary, Len Carter, represented the Society at the European Space Operations Centre (ESOC) at Darmstadt, in Germany, on March 13 and 14 to witness the encounter of Giotto with the near-nucleus of Halley's comet.

Those attending heard a welcoming address by Professor Lust, the Director-General of ESA, followed by a number of papers on the scientific objectives of the mission, the spacecraft itself and its operational aspects. Also included was a report on the first Vega results from Academician Sagdeev, of the Space Research Institute at Moscow.

The Encounter programme appeared on Eurovision TV which included continuous status reports from the main control room with inputs from the Science Centre, the Flight Dynamics rooms, etc.

The closest approach to the nucleus took place at two minutes past one a.m. on the morning of March 14, a fact particularly attractive to our Executive Secretary since it coincided with his birthday.

Return to the hotel was in the early hours with another stint following later in the day with overviews of the encounter, given by Dr. R. Reinhard, the Giotto Project Scientist, and presentations by the 11 Principal Investigators.

First BIS Gold Medallist

On April 12, 1961 Major Yuri Gagarin became the first man to orbit the Earth. His Vostok spacecraft landed safety in a prearranged area in the Soviet Union ofter completing one orbit of the Earth in a flight lasting 1 hour 48 minutes. It is now 25 years later and man has walked (and driven!) on the Moon and pushed the Space endurance record to 237 days. Soviet cosmonauts have spent in total more than 10 man-years in Space.

Yet, it was Gagarin's flight that signalled the arrival of a new era of spaceflight and a new era in the history of mankind. Appropriately, the Society awarded its first Gold Medal to Yuri Gagarin, "in recognition of his achievement of the first manned orbital flight round the Earth". During a memorable visit to this country in July 1961, the medal was presented to him by the Society's President, Dr. W. R. Maxwell at the Soviet Trade and Industry Exhibition at Earls Court, London on July 11, 1961.

38th International Astronautical Congress

BRIGHTON, 1987

The 38th International Astronautical Congress is scheduled to be held in Brighton from October 11 to 16, 1987. The principal venues will be the Brighton Conference Centre and the Metropole Hotel. The International Astronautical Congress (IAC) is the annual conference of the International Astronautical Federation (IAF) and its associated organisations, the International Academy of Astronautics (IAA) and the International Institute of Space Law (IISL). This will be the third meeting in the UK of this major world space organisation

The International Astronautical Congress has been held every year since its inception, in late summer or early autumn. The meetings last for a week, during which the principal activity is the presentation of an extensive programme of lectures covering a wide range of subjects that relate to the exploration and exploitation of space. During the Congress, the General Assembly of the IAF (its governing body) meets in plenary session to conduct its yearly business, with the guidance of a Bureau made up of its elected officers. The membership of the IAA and IISL and their management boards also meet during the Congress, as do the many committees of the three organisations.

The International Academy of Astronautics and the International Institute of Space Law were founded by the IAF in resolutions adopted by its General Assembly at the 10th IAC which was held in London in September 1959. Since then these two organisations have held their own meetings and lecture sessions at the annual Congresses.

The IAC does not have a fixed venue, but is held in various countries which have member societies of the IAF. It is the accepted practice that a voting member-society invites the Federation to hold a forthcoming Congress in its respective country. If the invitation is accepted, that member-society is charged with the responsibilities of hosting the Congress in accordance with the requirements of the IAF Secretariat, Bureau and International Programme Committee.

Dr. L. R. Shepherd

The British Interplanetary Society, which is one of the 12 original founders of the IAF and is its UK voting-member, has been charged by the General Assembly with the task of organising the 38th IAC following the acceptance of its invitation to the IAF to hold the 1987 Congress in Britain. Dr. L. R. Shepherd, BIS Vice-President and Chairman of the Society's International Liaison Committee is responsible for international negotiations and is actively engaged with the hosting arrangements.

The IAC has been held, so far, in 21 different countries in North and South America, Europe and Asia and has grown enormously in scale over the years. Twenty papers were presented in the first lecture programme at the 1951 Congress in London. The number of papers now presented has risen to around 500, with authors drawn from all the major space programmes in the world. Over this period, the number of member societies and institutions of the IAF has increased almost six-fold from the original twelve and now come from 35 countries. Other UK members of the IAF are the Astronautics and Guided Flight Section of the Royal Aeronautical Society and two recently admitted institutional members, the British Aerospace Space and Communications Division and Logica Ltd.

BIS Officers for 1986

Rex Turner, Society President.

At its meeting in February, the BIS Council re-elected Mr. C. R. Turner as President for a second one-year term. Dr. L. R. Shepherd was re-elected Vice-President for a further year. At the same meeting Mr. G. W. Childs took office as a new Vice-President, succeeding Mr. M. R. Fry whose three-year term of office had expired. Following the recent elections to Council (reported in the March issue of *Spaceflight*) Mr. C. R. Hume, MBE, joins the Council for the first time.

Mr. G. W. Childs was educated at Eltham College, Mottingham, Kent and George Watsons Boys' College, Edinburgh before entering Bristol University to study aeronautical engineering. On graduating in 1956 he joined the De Havilland Aircraft Company, Structures Department as a stress engineer in a team carrying out design, structural analysis and development testing of the Blue Streak Ballistic Missile airframe. In 1960 he became Section Leader working on airframe structural analysis of the DH125 business jet. The following year he returned to space projects as Senior Engineer, Design Department of the Space Division, BAC carrying out design and development of the Blue Streak airframe as the first stage of the ELDO A launch vehicle as well as on future project studies for ELDO B and C and high energy upper stages.

In 1967-68, Bill Childs advanced from Engineer-in-Charge Vehicle Design to Deputy Chief designer, Space Division assuming wider responsibilities as Assistant and, then, as Deputy Departmental Head for satellite design and future

Mr. G. W. Childs

project studies. Between 1968 and 1973 he was responsible as Chief Designer for the design and development of a range of spacecraft including ESRO IV, X4, GTS and OTS; for developments of the ELDO Launch Vehicle first stage; for advanced technology developments on propulsion and for future project studies for spacecraft, launch vehicles and space transportation systems. In 1980, he resumed his association with space projects as Chief Engineer, Space and Communications Division, BAe, being responsible for the design, development and manufacture of spacecraft, vehicle systems and equipment, technology development and future project studies. His present position at BAe, Stevenage, is that of Chief Engineer (Mechanical Equipment).

Mr. C. R. (Bob) Hume received his early engineering training in the Royal Electrical and Mechanical Engineers. He served in the ranks and was commissioned at the age of 23 from Warrant Officer. He attended higher education courses and served in a variety of posts mainly associated with the maintenance of anti-aircraft equipment. While commanding anti-aircraft workshops he produced schemes for improving the accuracy of fire and for this was appointed a Member of the Military Division of the Order of the British Empire in the New Years' Honours List of 1951. He went on to serve in MI10 and retired from regular service in 1957, when he joined the De Havilland Aircraft Company as a Senior Trials Engineer.

Bob devised a system of interlocking instructions subsequently called Contractors Standard Procedures which were used for the first launch of the Black Knight research rocket at Woomera in June 1958. These were used for setting up of the site and rocket and during the Countdown. He then transferred to the Blue Streak Project and became Chief Trials Engineer responsible for the development static firings of the Blue Streak rocket at Spadeadam during the period 1960-1963. He was appointed Deputy Officer in Scientific Charge (DOISC) on behalf of the Ministry of Aviation, of the F1 Blue Streak launch at Woomera and spent the period from August 1, 1963 to December 16, 1963 preparing the launch site and conducting the first static firing with a development model rocket. This series of tests was considered by the senior Ministry of Aviation Officer in Scientific Charge to have strongly contributed to the smooth operation of the Trials Team in the F1 trial. Bob continued as DOISC throughout the F1 trial leading to the launch on June 5, 1964.

On returning to the UK, Bob led a team of engineers at Hawker Siddeley to propose for the first ESRO contract for a scientific satellite known as ESRO II. On winning the contract he was appointed Project Manager and Chief Engineer. The programme schedule, starting on December 1, 1964 led to a launch on a Scout rocket in May 1967. Unfortunately, a malfunction occurred during 3rd stage burn and the 4th stage did not ignite. As a result the ESRO II satellite failed to orbit as planned. The back-up satellite was successfully launched a year later and performed its mission completely. The project was a trial blazer in ESRO, later to become ESA, and many notable European space personalities including Roy Gibson, Professor Lüst, Dr. Edgar Page, George Van Reeth and Ants Kutzer were part of the overall management team.

In 1967 Bob Hume moved to the RCA Space Center at Princeton, New Jersey and became a member of the Vice-Presidents Staff as Manager of Programme Management. During the 13 years at RCA he was associated with all the RCA Space Programmes including TIROS and DMSP. Bob was particularly involved with space communications, managing the RCA Satcom programme in 1973 and 1974 which was the first three-axis communications satellite using frequency re-use and which flew on the first Thor Delta 3914 launcher. He also managed the Anik B communication satellite programme with duel frequency usage which had not been previously accomplished.

Management of the Viking Lander communications system and the colour camera on the Moon were also part of his responsibilities. Viking Lander gave the first pictures of the Mars surface while the colour camera gave TV pictures world-wide of the Apollo 15 mission from the Moon.

Mr. C. R. (Bob) Hume

In 1979 Bob returned to Europe and became a consultant. During the next three years he consulted for various companies, although mainly for Matra. Whilst with Matra he acted as Proposal Manager for the Satcom International's Aussat bid. Arising from this experience he suggested the need for a new satellite bus which eventually became Eurostar.

In April 1983 he joined Marconi Space Division at Portsmouth to manage the Skynet 4 Military Communications Payload and Ground Equipment Project. This design was completed by Marconi who manufactured 85 per cent of the payload equipments at Portsmouth. Since December 1984 an engineering Model and two Flight Payloads have been completed ready for assembly to the satellite bus. Latterly, Bob has been appointed Business Operations Manager at the new Marconi Space Systems Ltd. (MSSL) including Skynet, Olympus, Meteosat and ERS-1.

He has published 12 papers and lectured in Europe, USA and Australia. In his long experience in Space he has met many well known space personalities and astronauts together with appearing on TV and radio in all three continents.

SPACEFLIGHT BY AIR MAIL

With this issue of ***Spaceflight,*** the Society offers an Air Mail delivery to overseas readers in non-European countries. This service is now possible following the introduction of new label addressing equipment at the Society's Offices. The advantage is considerable for readers in the US, Canada, the Far East and Australia who exprience delivery times of four to six weeks by surface mail.

Requests for Air Mail delivery need to reach the Society by the 14th of the month to be effective for the next month's issue and should enclose a remittance of US$2.50 (£1.50 sterling) per issue for each remaining 1986 issue.

LIBRARY REPORT

Main Library

Our Society is continuing to make a strong and positive effort to establish itself as a Centre of Learning, with its Library and proposed archives as essential aspects of this work.

Interest in the Library's collection of books and reports continues to grow, as borne out by the increasing number of members seeking to research some aspect of space activity. The early decision to specialise our collection has proved of great benefit. Although a representative collection of popular works is still held, most volumes are specialist works printed in relatively small numbers and not thus easily available elsewhere. This, at the same time, explains the slow growth in our collection. We no longer merely add books but include only those specifically required.

Our current Library stock is as follows:

Books	2,600
Reports	4,700
Total	7,300

Among recent works presented to us was a book of Tycho Brahe from Donald Larson, one on Space Law from Paul Sowerby, a History of Rockets and Space Travel from Francis Fears, an Encyclopaedia of Space and many incidental publications by Michael Stone and a Biography of John Glenn from Kimperley Baker. There was also a book on comets from Mike Hendrie while two books, duly inscribed by their author, arrived from Henry S. F. Cooper Jr with a note offering help in obtaining other similar material of interest. Captain John London produced a number of interesting papers and an Apollo recording, while even back issues of "Spaceflight" which proved very useful, arrived with a number of photographs from Phil Heard.

Our thanks go to all these donors both for their generosity and goodwill.

Society Records

One of our main activities, surprising thought it might seem at first sight, is to endeavour to collect early Society records and to create an archive of Society activities.

Little has survived the years but John Maynard produced some early magazines, correspondence and similar items which threw light on the immediate post-war years. We still lack much to do with our early meetings, including the two London Congresses of the International Astronautical Federation held in 1951 and 1959, but are still hopeful that such material will turn up.

First Day Covers

The Society's collection of First Day Covers has now reached a respectable size, as also has its collection of space medallions. Most of the latter are of relatively recent vintage, for example a specimen of the AIAA 50th Anniversary medallion kindly given by Jim Harford. It seems unlikely that we shall have the good fortune to accumulate early comet medallions, though we have found one contemporary with Cheseaux's Comet of 1744 and the gold coin issued within a year or two of the appearance of the Crab Nebula in 1054.

Special thanks are due to Keith Wright and Rex Hall, who have continued to supply European and Soviet covers respectively, and to Gisela Grunewald, Chief of the UN Postal Administration, for a complete set of all UN covers relating to space, as well as to Geoff Perry – among many others – who provided occasional gifts.

We have, somewhat incidentally, managed to accumulate a collection of space stamps. One very nice albumn contains a complete set of Apollo-Soyuz stamps from all over the world, together with the signature of Aleksey Leonov and Valeriy Kobosov, who took part in the ASTP joint flight from 15-21 July 1975.

Our thanks are due to Eric Stevens, representative of a number of members who have forwarded space stamps to us.

Archive

We have identified an initial target of duplicate copies of some thousands books and reports, grouped under a number of headings, worth holding in a permanent collection for a basic Society archives.

An account of a few of these appear below:

(a) Notwithstanding that Halley's comet proved a disappointing object to the casual observer, our collection of memorabilia and general books on comets is now representative and approaching 80, all of recent vintage.

(b) A new venture lies in building up a collection of early Prints relating to space. Such items usually sell at a premium. It is somewhat late in the day to start such a collection but it is essential to do so if our Society is to become a full repository of space learning.

(c) We have started a special collection of biographies and of books and literature written by or relating to astronauts, space scientists, space engineers and pioneers of astronautiacs. There is still a long way to go in this area.

(d) The same applies to books on eclipses of the Sun and transits of Mercury and Venus most of which are now regarded as antiques, but there is better news on the star maps front. Here, although most early items are denied to us by virtue of cost, we already have a good holding of current material.

(e) The proposed sound archives received a boost with a collection of Shuttle launchings from Esa Anttolainen and a tape recording of the first Blue Streak launching from Professor Ian Smith. One

Society Fellow Douglas Arnold was among those at the memorial service in the USA for the seven Challenger astronauts and he took these pictures. On the left Neil Armstrong can be seen talking to Karl Henize, Spacelab 2, and Owen Gasriott, the Spacelab and Shuttle veteran. On the right some of the bereaved families join other mourners before the President's arrival.

problem with sound recordings are that they come in differing shapes, sizes and sound tracks, so we will one day have the considerable problem of placing all these on a standard basis.

(f) We have also been fortunate in adding a few more space models to our Library display, with one from Bob Hume and another from President Layton at RCA. All who use the Library find them attractive and hope to see the collection enhanced. As it stands, we still have another 20 to find.

Future Plans

The Library Committee has identified a need to make our HQ as interesting as possible to members and visitors. Knowing that this cannot be done immediately, they have set up a 25 year plan, with actual progress depending on enterprise, support from members and the availability of finance.

What a crew! Bill McLaughlin, voyager Flight Engineering Manager (left), Len Carter, BIS Executive Secretary, and Donna Wolff, deputy Voyager Flight Engineering Manager, discussing the finer aspects of the Voyager spacecraft, while standing in the Voyager Mission Support Area at the Jet Propulsion Laboratory The picture was taken during Mr Carter's visit to JPL for the January Voyager encounter with Uranus (see *Spaceflight*, March 1986, for report).

CHESEAUX'S COMET OF 1744

Cheseaux's comet must have been a most beautiful object. Its remarkable form was at its clearest on March 8, 1774 when all six divergent branches of its tail extended from the nucleus in luminous curves.

The Library Committee had cause to re-examine this striking event from the past on the acquisition of a German Medallion, issued in the same year. This Medallion shows the comet poised above a tree-lined landscape but, surprisingly, with only two well-defined tails, though there is suspicion of a third (a jet) between them.

The reverse contains the inscription "Wer hat des Herrn Sinn erkannt? – a Biblical reference to Romans Ch.11, V.34. Translated into English this reads: "Who knows the mind of the Lord?".

SPACE STATION EXPLOITATION

Such has been the demand to participate in the Society's forthcoming symposium on Space Station exploitation, scheduled for May 21 and 22 next, that practically all places were taken before the programme had even been formulated.

The meeting, the third in a series devoted to studies of the Space Station, is designed to break new ground. The aim is to provide a series of updated overviews on progress – political, administrative and technical – followed by updated accounts on advances in the technology but with the main thrust devoted to utilisation.

In general terms, the aim is to consider a "user-friendly" Space Station and develop techniques of how this might operate in the most effective manner. At the same time, ideas are needed for new users for the Space Station, some of which are mere gleams in the eye at present. The range of uses involves both science and industry, frequently on an international basis.

In the current meeting microgravity aspects are developed further, together with, particularly, papers exploring biomedical and bioprocessing aspects. Breaking yet further ground is another paper on how the Space Station might be used for pharmaceutical research and manufacturing.

PROMOTION

We have frequently urged members to make known the Society's aims, activities and publications to friends and colleagues, whenever they have an opportunity of doing so. For most members, this is a matter of individual conversation but many other opportunities can arise, as our postbag testifies.

For example, Mel Smith referred to the Society in his book "An Illustrated History of the Space Shuttle" while Tim Furniss did the same in his "Guinness Book of Space Flight Records". A paper in the *Reader's Digest* for September 1985 on SETI quoted a comment from Dr. Tony Martin, a former Vice-President of the Society, while Tim Furniss surfaced yet again in *Flight International* of October 19 last, this time recalling the pressures exerted by the Society over the past 25 years for the establishment of the British National Space Agency. David Hardy, too, gave several mentions to the Society in his articles in *Space Voyager*, during which he referred readers to both ***Spaceflight*** and ***JBIS***.

THE PERSEID PROJECT

Members may be interested in exercising their astronomical talents in support of a good cause by associating themselves with this Project. The basic idea is to raise funds for the National Society for the Prevention of Cruelty to Children through sponsored meteor watches – and members do not have to be experienced observers to take part!

The project runs from July 23 to August 20 when the Perseids regularly give high rates and outside temperatures are reasonably good. Observers are sponsored by friends and relatives for each meteor observed, and just a couple of hours of observation spread over a few evenings should suffice. Sponsorship forms and Report sheets can be obtained on receipt of an SAE from British Meteor Society, (Perseid Project), 26 Adrian Street, Dover, Kent, CT17 9AT.

MAY 1986

Spaceflight

The International Magazine of Space and Astronautics

Vol. 28 No. 5

CONTENTS

Editor:
G. V. Groves

Assistant Editor:
C. A. Simpson

Managing Editor:
L. J. Carter

Editorial Office:
27/29 South Lambeth Road,
London, SW8 1SZ, England.
Tel: 01-735 3160.

Spaceflight is published 10 times a year and is distributed internationally by post to:

1. Members of the British Interplanetary Society, free of charge.
2. Individual purchasers for personal use at £2.00 (US$4.00) per issue (1986).
3. Libraries at an annual institutional subscription (1986) of £30.00 (US$50.00) inclusive of issues of *Space Education* Magazine.

For Air Mail delivery to non-European countries add £1.50 (US$2.50) per issue. All subscription payments should be sent to the Editorial Office (address above). Details of application for membership of the British Interplanetary Society are available from the Executive Secretary, the British Interplanetary Society at the same address.

* * *

Editorial and advertising enquiries should be addressed to the Editorial office. Responsibility for security and all other clearances necessary for publication rests with the author. Manuscripts are accepted only on condition that all such matters have been completed. Opinions in authored articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

* * *

Published by the British Interplanetary Society Ltd., (No. 402498) Registered Office: 27/29 South Lambeth Road, London SW8 1SZ, England.

Vol. 28 No. 5 May 1986

Front Cover: A painting of a Lunar supply base that could be typical of the projects suggested in the new report by the United States National Commission on Space (see page 194). The picture shows a base being constructed to supply Lunar materials to chemical plants in space. The horizontal cylinders contain the living areas, maintenance facility, soil packaging plant and loading facility for the Lunar mass driver, an electromagnetic cannon designed in this scheme to eject 4 kg packages of soil from the Moon to deep in space for collection. *J.S.C.*

Space robotics in action – automated rovers work together on the surface of Mars

In this special 17-page section *Spaceflight* focuses on the future in Space and some of the exciting proposals in the new report of the United States National Commission on Space. There are also articles by Arthur C. Clarke on his 'Visions for the Future', James R. French, of JPL, on future deep space missions, Phillip Clark, on a Soviet Mars sample return mission, and Dr. Harry Joyce, who discusses a future propulsion concept.

Human settlements on the Moon and Mars are among the many ambitious targets for the next 50 years identified by the US National Commission on Space which reported in mid-April after a year-long study.

The report, "Pioneering the Space Frontier: Our Next 50 Years", envisages interplanetary factories and a new range of spacecraft to support the goal of permanent space settlements. It describes a vast expansion in space travel and commercial development for the first quarter of the 21st Century and estimates there could eventually be one million passengers a day, an extrapolation based on the growth in air transport over the past five decades.

The National Commission on Space, chaired by Tom Paine, a former NASA administrator, has recommended that three new space transport craft become operational within 15 years together with an orbital spaceport. One of the new spacecraft would be the Trans-atmospheric Vehicle (TAV) or spaceplane with the capability of taking off from a normal runway (*Spaceflight* March 1986). Development of this is already proceeding apace with $300m contracts for a full-scale engine demonstrator and airframe work already issued by NASA and the Department of Defense. The new spacecraft would follow on from the Space Station which is currently due to become operational in the mid-1990s.

The Space Station would be the first stage of a series of space facilities in low Earth orbit which would include a spaceport and variable gravity research laboratory. The concept is extended under the theme "Bridges Between Worlds" to encompass, ultimately, a network of spaceports between the Earth, Moon and Mars.

During the first five years of the 21st century spaceports would support initial robotic operations on the lunar surface followed by a manned outpost which would develop by the year 2017 into a permanent settlement and manufacturing plant.

At a similar time the Commission envisages the spaceport concept being extended to Mars as a base for robotic exploration and a manned outpost. An initial Martian base could be established in 2022 and within five years this could become a full-scale base with manufacturing capacity.

The timetable (see Fig. 1) for this kind of development is derived in financial terms from a predicted growth rate of 2.4 per cent in both

Figure 1. Timetable for Settlements.

LUNAR	
Manned Outpost	**2004**
Pilot Propellant Plant	**2007**
Full-scale Production	**2012**
Full-scale Manufacturing	**2017**
MARTIAN	
Manned Outpost	**2017**
Initial Base	**2022**
Full-scale Base and Manufacturing	**2027**

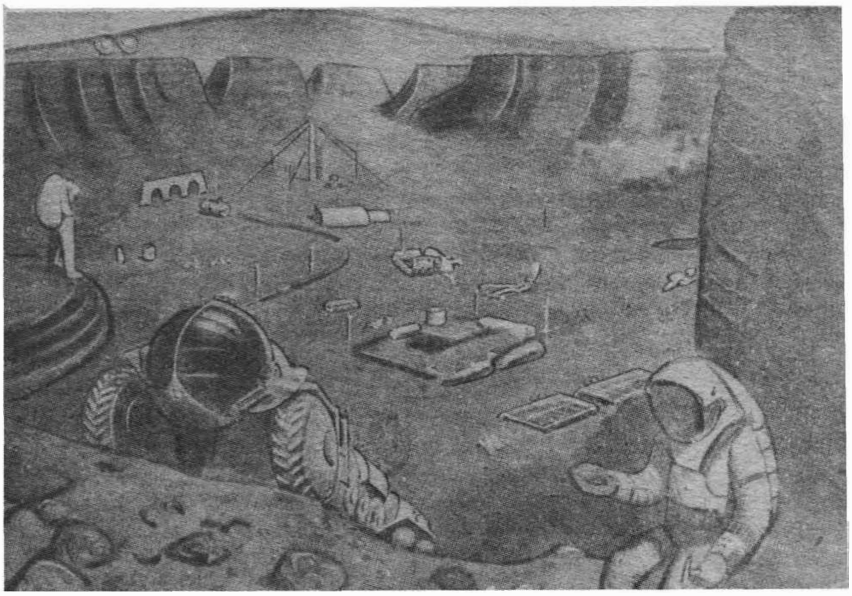
the NASA budget and the US gross national product per year.

NASA's current budget is $7.3 billion and the Commission assumes that will have doubled by 1995, at which time the Space Station should be operational. Expenditure from then onwards would total $700 billion on all the projects outlined in the report (no individual breakdown is given) spread over the ensuing years. It is envisaged that industry would contribute up to 25 per cent of this.

Other key areas identified by the Commission are:

- Launch of a Mars sample return mission.
- Investigation of asteroids that could be exploited for mineral and other resources.
- Continued development of electrophoresis techniques for the purifying of chemicals.
- Development of high performance electric propulsion systems.
- Construction of self-sustaining biospheres enclosed ecological systems or "greenhouses" independent of Earth.

The report by the National Commission on Space is the latest in a series of forward-looking documents designed to steer the United States into the space future.

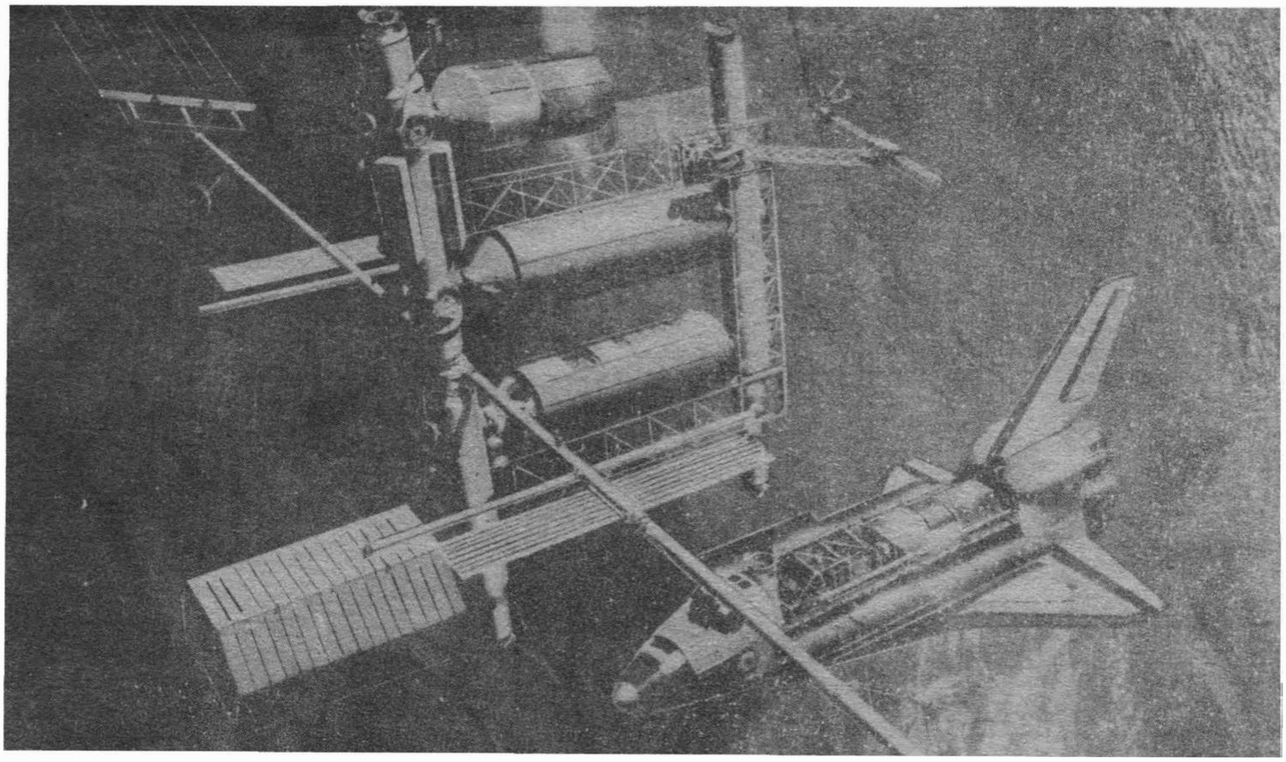


Artist's concept of a manned base on Mars.

Figure 2. Planned activities for 1975-79 compared to those actually achieved

DATE	PROGRAMME	ACTUAL DATE
1975	Space Shuttle test flight	1980
1975	Space Station module test flight	1980(Spacelab)
1975	Space Tug test flight	not planned
1975	Venus Orbiter	1979(Pioneer)
1976	Space Station in Lunar orbit	not planned
1977	Multiple planet tour	1978(Voyager)
1978	Jupiter Orbiter	1987(Galileo)
1979	Space Station in synchronous orbit	not planned
1979	Lunar Station	2004
1979	Mars excursion module test flight	not planned

The Space Shuttle pays a visit to a future Space Operations Centre in low Earth orbit. The concept is considered as a staging station for supporting a host of Space programmes.



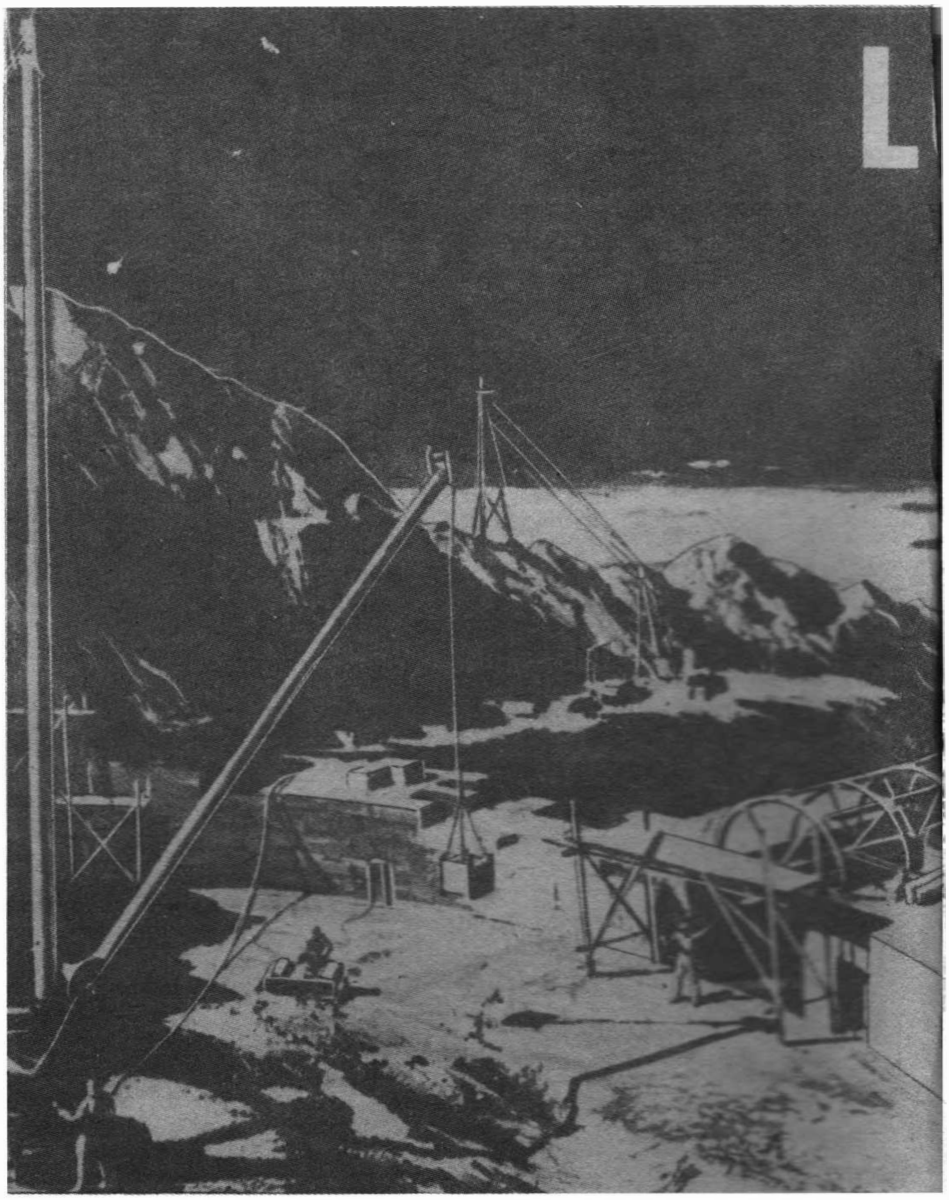
One of the first was in 1959 when the newly formed NASA published a ten year plan of its objectives. These included developing a wide range of launch vehicles and the first manned space flights, culminating with a circum-lunar mission by the end of the decade. A lunar landing by men was not expected until the mid-1970s.

Ten years after NASA's first report, as man walked on the Moon for the first time, President Richard Nixon commissioned a similar planning exercise for the 1970s. The report, "America's Next Decade in Space", proposed a new series of objectives and was reasonably accurate for the first five years, highlighting a Mars orbit mission (Mariner 9), Apollo Applications Workshop (Skylab), Mercury/Venus flyby (Mariner 10) and a Mars soft landing (Viking).

However, subsequent predictions (see Fig. 2) became less accurate as the political climate towards Space shifted, causing delays for many of the programmes and cancellation of others.

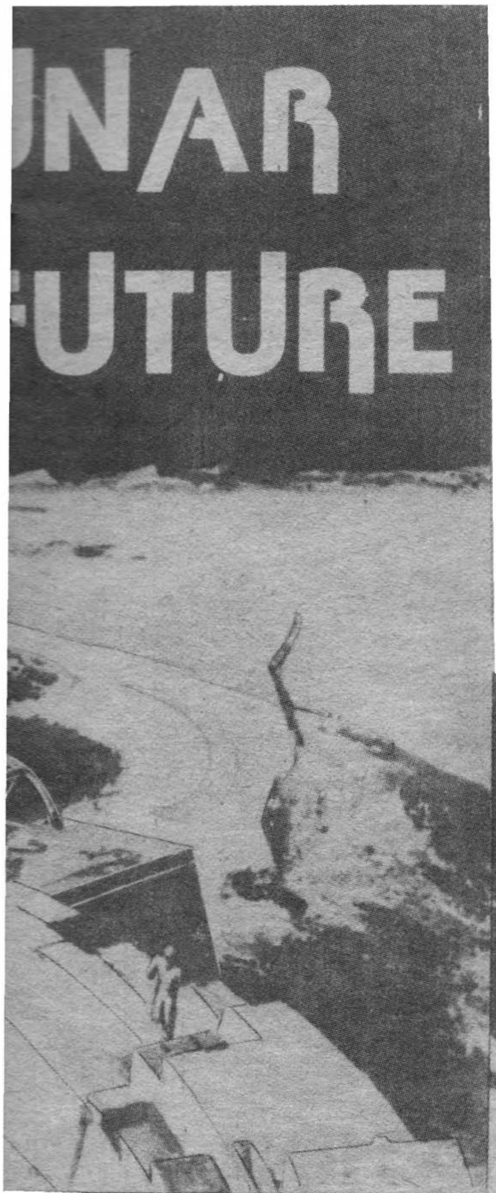
A key to achieving a selection of the goals outlined in the new report will be detailed analysis and a strong commitment to the projects chosen by the politicians and decision-makers involved.

Colossal energies will have to be harnessed to steer the United States on such a bold course into the Space Future, especially if there is to be no repeat of the problems that threatened and distorted the space programmes of the mid-70s.



1061

A Permanent Moon Base



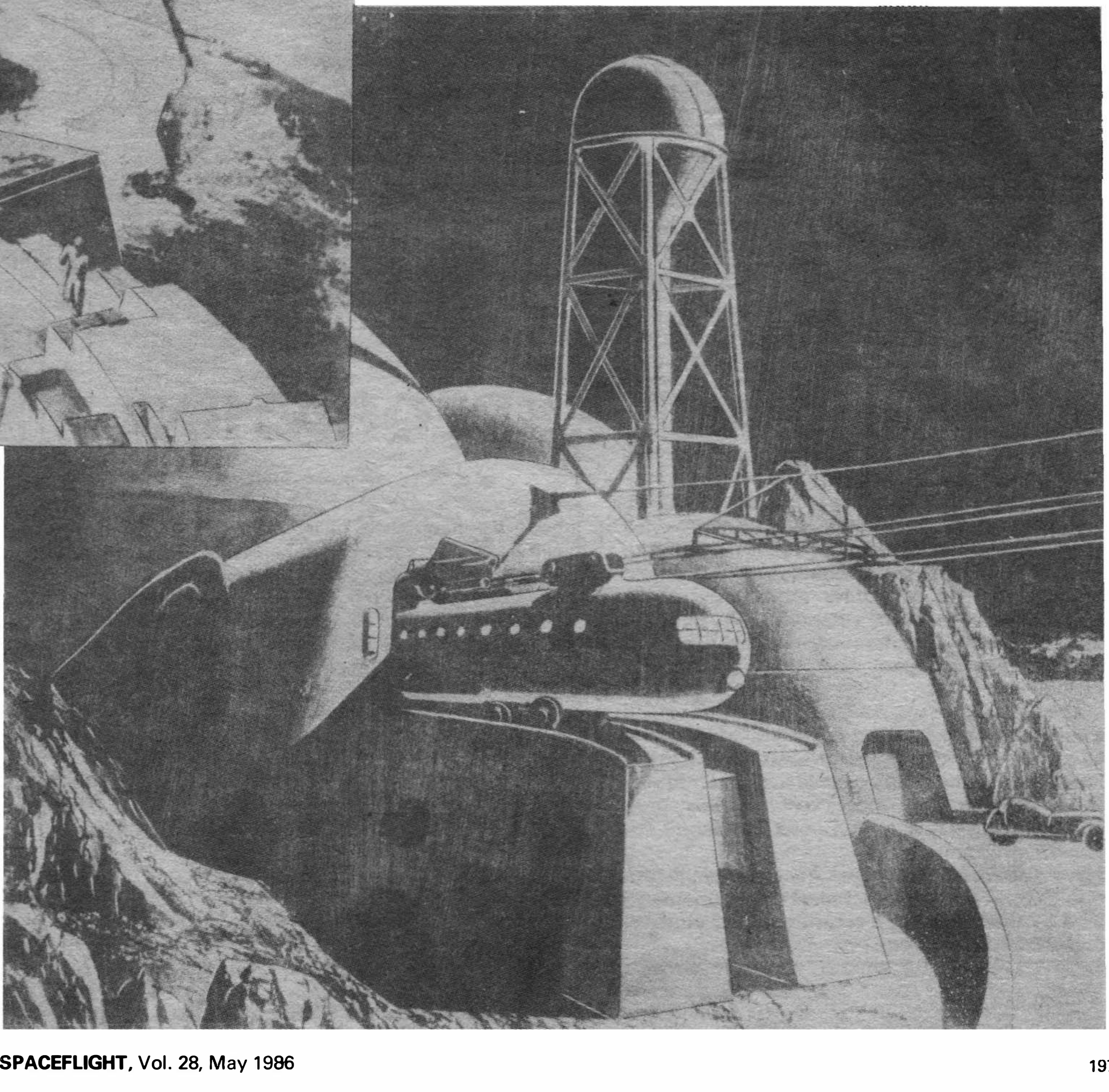
Permanent lunar structures (left) would be constructed from local materials. Rock is being cut from the cliff in the background and used to build up the walls of a dome. The dome would be made airtight by lining it with a plastic sheath, but in the lunar vacuum the internal air pressure would tend to blow it apart. The weight of the dome is being used in the design shown to contain the air pressure.

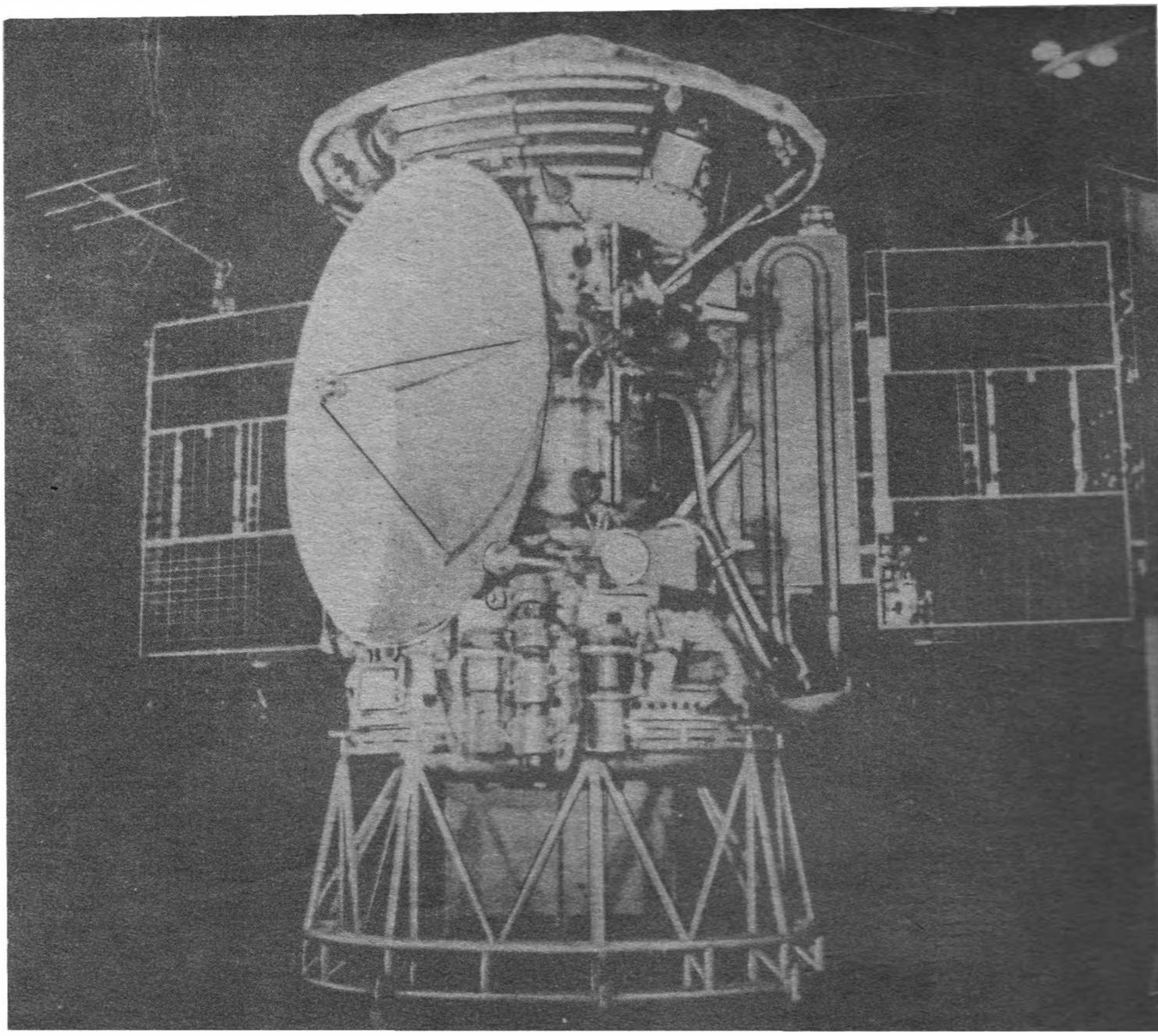
In this situation the lower lunar gravity is a disadvantage and a massive structure is called for as indicated by the thickness of the walls. The framework on the far side of the dome marks the position of the airlock through which men and vehicles can enter from the roadway outside.

The construction of larger lunar bases (below) would be expected to evolve into true cities in the form of interconnecting domes. Some domes would be residential and others devoted to food production and the other services and activities of a self-supporting community, which may then be linked to other settlements by overhead transport. The scene depicts the road and cable entrances through airlocks.

The overhead car is shown with hemispherical ends as it is internally pressurised. On entering the airlock its weight is taken up by its wheels and the cradles from which it is suspended are left outside the airlock until it re-emerges. The structure on a supporting tower in the background is a small observatory.

Paintings: *R. A. Smith*





The Mars 3 craft achieved orbit about the planet in 1971 and its descent capsule transmitted part of a surface picture.

MARS SURFACE EXPLORATION

by Phillip Clark

The Soviets have not flown a mission to Mars since the launch opportunity of July-August 1973. With the approach of the next launch window in May 1986 and further opportunities to follow at roughly 2-year intervals, interest has heightened into possible missions of surface exploration aimed firstly at returning surface samples and then at manned exploration.

Spaceflight **(1986, page 113) has already reported on a Soviet mission that is to be flown in July-August 1988 to rendezvous with either or both of the natural satellites (Phobos and Deimos) of Mars and to deploy a lander on Phobos. The setting up of the Mir space station further enhances the Soviet capability for interplanetary missions.**

We now report on possible surface sample-return missions to Mars and their technical requirements as identified by the author in a recent detailed study of the Soviet Mars Programme [1]

Launch Vehicles

It has been reported that the Soviet Union is about to introduce a new family of launch vehicles. While these could be used to support a Mars Sample Return Mission (MSRM), their performances are still unknown. Therefore, it has been assumed that the Proton SL-12 will be used. This can place up to 25 tonnes into low Earth orbit and the high performance escape stage used for earlier Mars missions would allow about 6 tonnes to be launched to Mars.

Mission Requirements

Calculations are simplified if it is assumed that trajectories close to the minimum-energy paths are used, though from a design viewpoint they involve the maximum spacecraft lifetimes. Soviet satellites are often short-lived but Venera (Venus) probes performed successfully for 2-3 years.

Table 1 notes the launch and other event dates assumed for the study while Table 2 summarises the velocity requirements for the missions. It is assumed that for launches in either 1994 or 1996 four spacecraft will be used: this would match the launch rate of 1973 when Mars 4-7 were launched to that planet. There will be two pairs of craft: one pair will be combined orbiters and Earth

return stage vehicles, while the other will be combined fly-by buses and landing/ascent craft.

Flight Plan

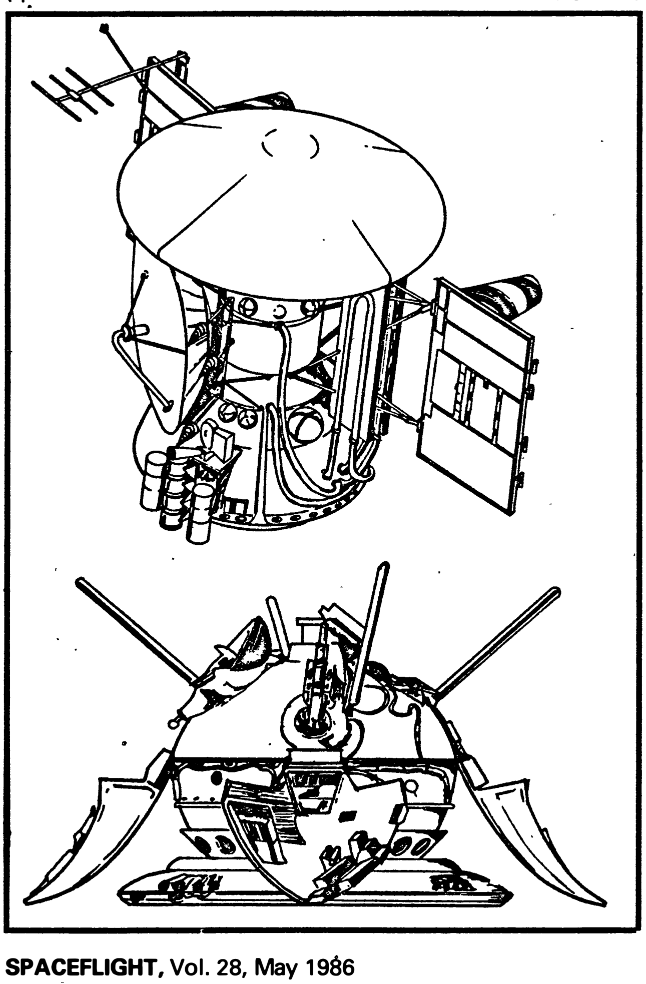
In preparing a flight plan, one was chosen that is applicable either to 1994 or 1996, with slight changes owing to the differing energy requirements. Each launch will place a two/three-part spacecraft initially into a low Earth parking orbit. About 70 minutes after launch the booster's escape stage ignites to place the spacecraft into its heliocentric, trans-Mars trajectory.

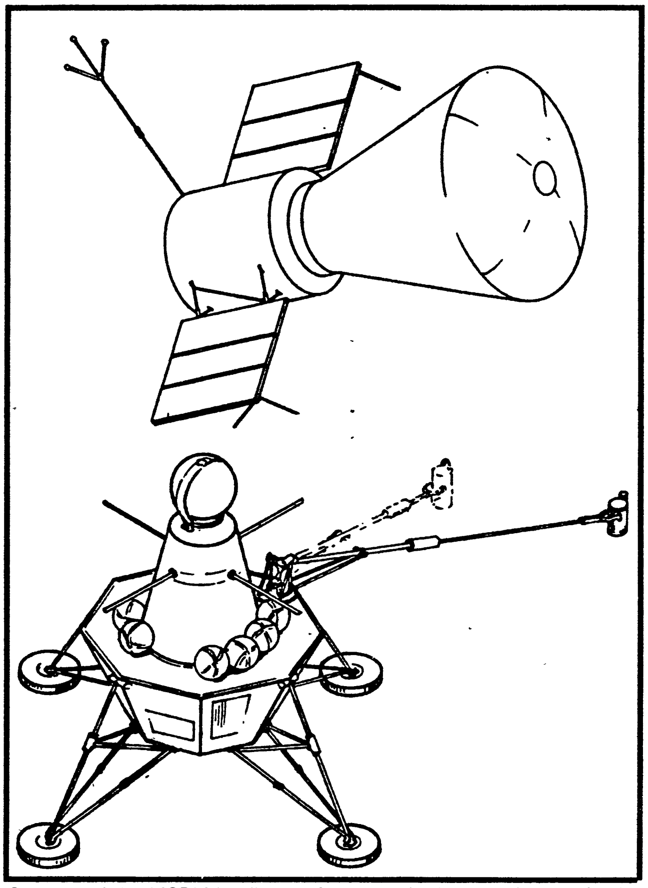
After a coast lasting about 10 months, the orbiter complexes arrive first at Mars, slotting into a 2,000-32,050 km orbit inclined at 0-30° to the equator. The orbital period matches the 'day' on Mars. The craft then use cameras to map carefully the proposed landing sites and, if necessary, search for back-up landing sites.

About three weeks after the orbiter complexes arrive, the lander complex approaches Mars. The lander itself, inside a heat shield, separates from the fly-by bus and makes a direct entry into the atmosphere, followed by a soft-landing. The landing is made using aerodynamic braking, parachutes and, finally, retrorockets. The fly-by module continues in heliocentric orbit, since it was required only for 'housekeeping' working during the trans-Mars coast.

After a few days on the surface, a remotely-controlled 'arm' takes a sample of surface material and places it in a spherical Earth-return capsule. Preparations are then made for launch into orbit about Mars.

The second generation Mars probe as flown in 1971. The complete orbiter/lander craft is shown at top while the landing capsule as deployed on Mars is shown at bottom. The Mars 6 and 7 craft, launched in 1973, were identical in appearance with the Mars-1971 spacecraft. *R.F. Gibbons*





Concept of the MSRM landing craft. At top is the complete craft; the lander (designed with Luna 16 in mind) is at bottom.
P.S. Clark & R.F. Gibbons

Meanwhile, the orbiter complex has manoeuvred in orbit, the altitude being shifted to 200-32,050 km. The single stage ascent vehicle lifts-off and reaches this orbit, with the final rendezvous conducted by the orbiter vehicle. The Earth-return capsule docks with a cone on the Earth-return rocket stage carried on the orbiter.

The ascent stage of the lander separates and the orbiter with its precious cargo returns to its original orbit, where it remains for 11 months until the optimal trans-Earth launch opportunity opens. Earlier launches could be made back to Earth but these would involve larger velocity manoeuvres and would therefore allow less payload.

When the return opportunity opens, the Earth return rocket separates from the orbiter and fires to take the capsule out of Mars orbit. The journey back to Earth takes about 11 months, followed by a direct entry into the Earth's atmosphere, landing by parachute in the Soviet Union.

Spacecraft Requirements

In scaling the various elements of the spacecraft it was assumed that the maximum mass that could theoretically be used *is* actually flown to the planet. The requirements vary with the launch and other event dates so the figures given here are only a guide.

The orbiter has been assumed to be similar to the second generation Mars/Venera spacecraft 'buses,' with suitably enlarged fuel tanks. Instead of the descent craft carried on these mission, the MSRM carries a small Earth-return rocket stage.

As a guide for the descent vehicle, the design of the Luna sample-return craft that brought back lunar samples automatically in 1970-1976 has been relied upon, although the MSRM craft must be heavier because of the

Table 1. Suggested target dates for the MSRM.

Event	Orbiter Spacecraft	Fly-by/Lander Spacecraft
Earth launch	1994 Oct 18 Oct 23	1994 Nov 2 Nov 7
Mars orbit	1995 Aug 24 Aug 30	
Mars landing		1995 Sep 19 Sep 25
Trans-Earth	1996 Sep 5 Sep 11	
Earth recovery	1997 Aug 22 Aug 27	
Earth launch	1996 Nov 13 Nov 18	1996 Nov 28 Dec 3
Mars orbit	1997 Sep 3 Sep 9	
Mars landing		1997 Sep 29 Oct 5
Trans-Earth	1998 Nov 11 Nov 17	
Earth recovery	1999 Sep 29 Oct 4	

This Table provides the target dates for critical events in the MSRM design study. They have been used to scale the possible missions launched in 1994 and 1996 but it should not be assumed that they are actual dates which will be used.

Table 2. Velocity requirements for MSRM.

Event	1994 Launches		1996 Launches	
	Orbiter m/s	Lander m/s	Orbiter m/s	Lander m/s
Trans-Mars inj	3,685-3,700	3,645-3,665	3,625-3,635	3,590-3,600
Mid-course	100	200	100	200
Mars orbit inj	1,635-1,720	-	1,825-1,885	-
Orbital trim	50	-	50	-
Rendezvous	190	-	190	-
Mars launch	-	4,910-4,940	4,910-4,940	-
Trans-Earth inj	1,320-1,340	-	950-975	-
Mid-course corr	100	-	100	-

With the dates given in Table 1, these are the velocity requirements for the MSRM in 1994 and 1996. Abbreviations are 'inj' (injection) and 'corr' (correction). The mid-course correction on the lander missions allows for a 100 m/s deflection by the fly-by bus after separating from the lander complex.

Table 3. Masses of the MSRM craft.

	1994 Launch kg	1996 Launch kg
ORBITER COMPLEX		
Orbiter bus	5,455-5,460	5,625-5,630
Earth return rocket	370-365	325-320
TOTAL	5,825	5,950
LANDER COMPLEX		
Fly-by module	1,000	1,000
Descent equipment*	1,635	1,690
Descent stage	1,490	1,505
Ascent stage	1,775	1,875
TOTAL	5,900	6,075
Mass landed on Mars	2,775	2,875
Earth return capsule	85	100

A summary of the derived masses of the various components of the MSRM craft: further details can be found in Ref. 1. The item marked '*' represents the heat shield, parachute system and other equipment separated during the descent, but not the rocket fuel.

greater velocity requirements. The lander is carried to the vicinity of Mars in a heat shield assembly attached to a small 'housekeeping' flyby craft. This could have the appearance of a stretched version of the American Vikings.

The lander is a two-stage craft, having a single stage with retrorockets for landing and carrying surface experiment equipment. It was decided to use a single stage to carry the return capsule from the surface for simplicity (for the range of masses studied there was only a small advantage in using a multi-stage ascent rocket).

Table 4. Future launch opportunities to Mars.

Launch Window	Arrival Window
1986 May	1986 Nov-Dec
1988 Jul-Aug	1989 Feb-Mar
1990 Sep-Oct	1991 May
1992 Oct-Nov	1993 Jun
1994 Nov	1995 Jul-Aug
1997 Jan	1997 Aug
1999 Feb-Mar	1999 Aug

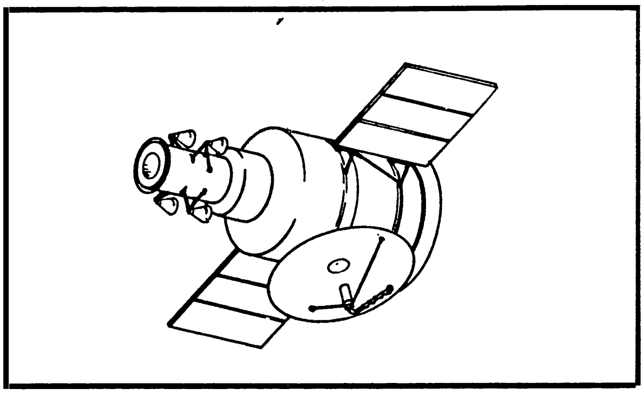
These dates are only approximate and launches for Type 1 trajectories could come a week or so to either side of each period noted above, with a similar difference applying to arrival dates. The Type 2 trajectory launch windows begin about 4-6 weeks earlier than those for Type 1, with arrivals about 4-6 weeks earlier than those for Type 1

Generally, the velocity requirements for the lander depend only upon the inclination of the orbiter's circum-Mars orbit. The values in Table 3, representing a mass breakdown for the mission, assume inclinations from 0° (equatorial) to 30° north or south.

Closing Comments

It is reported that, after a break of ten years, Soviet interest in Mars missions is being re-kindled and that orbiter (and lander ?) missions are being planned for the late 1980's. In addition, some observers have suggested

Table 4 presents a list of the nominal 'Type 1' launch windows to Mars to the end of the century. The windows for 'Type 2' trajectories (assumed here) require launches about 4-6 weeks earlier than listed and Mars arrivals 4-8 weeks after the date quoted.



Concept for the MSRM orbiter showing the Earth-return stage. The main bus could be based upon the second generation Mars probe but with a greater propellant capacity. *P.S. Clark & R.F. Gibbons*

that a manned Mars expedition is being seriously considered for the 1990's or the first decade of the next century. Either way, a major scientific achievement would be the recovery of soil samples by automatic spacecraft in the next decade or so.

REFERENCE

1. P. Clark, "The Soviet Mars Programme," *JBIS*, (to be published).

In the preparation of the MSRM discussed here and in more detail in Ref. 1, NASA's TM X-3184 'Automated Mars Sample Return Mission Concepts for Achievements of Essential Scientific Objectives' proved to be invaluable.

VISIONS OF SPACE

By Arthur C. Clarke

Arthur C. Clarke, a past Chairman of the British Interplanetary Society and now one of the world's leading science fiction authors, considers some of the possible futures and pitfalls for Mankind.

Arthur C. Clarke.

Introduction

The very first science fiction magazine I ever saw, as a 12-year old boy, was Hugo Gernsback's *Amazing Stories* for November 1928. The splendid cover, by Frank R. Paul, showed Jupiter filling most of the sky and was enough to fire the imagination of any teenager. The amazing thing about that picture was the details of the Jovian atmosphere - loops and whirls and eddies - that were completely unknown until the Voyager mission in 1979. I still get a strange feeling when I compare this old magazine with the images beamed back from Jupiter half a century later.

I believe it was the astronomer Robert Richardson who introduced the concept of the gravitational well - already familiar to nuclear physicists - into discussions of space flight. The idea that we're at the bottom of an imaginary crater four thousand miles deep, with frictionless walls we can't get a grip on, dramatises our predicament here on Earth.

It may seem bad luck that we were born at the bottom of that deep hole and have to work so hard to get out of it. It might sound nice if we lived on a world of much lower gravity like Mars, the Moon, or even one of the asteroids but, by being engineered for 1g, we can function happily anywhere else in the Solar System; I believe that Edgar Rice Burroughs' energetic hero, John Carter, was the first to discover this, when he arrived unexpectedly on Mars.

This reminds me that, some 30 years ago, the late J.B.S. Haldane told me that the human race had obviously been designed for interstellar travel because, at a comfortable 1g for one year, one could get to the speed of light!

Since the sides of our infamous gravity well are so slippery, we have to escape in one giant leap. The rocket still remains the only practical way of doing this, which leads us to another piece of back luck. If the well was about 10% less deep, we could escape fairly easily with a *single* stage - that is, a fully reusable - rocket. As it is, we need at least a stage and a half - which is one way of describing the Shuttle.

Incidentally, back in 1952 I described a much nicer-looking shuttle than the unendearing space truck that NASA uses; it had four drop-tanks, symmetrically arranged around the main body. You'll find it in the frontispiece of *Islands in the Sky* - but I can't take credit for the basic idea. That had been worked out by my colleagues in the British Interplanetary Society a few years earlier.

Latterly, some very bright engineers have persuaded the DTI that not only could they make a single-stage-to-orbit spaceship, but one that can take off horizontally, like an ordinary aircraft, a much more attractive idea for paying passengers. It duly provoked a tongue-in-cheek comment from French Research and Development Minister Dr. Curien who said "First you build a fighter that takes off vertically. Now you want a launch vehicle that takes off horizontally."

Whatever refinements may emerge in rocket design over the next decades, or centuries, it seems that this brute-force method of escaping from Earth will always have fundamental limitations. No major improvement in *chemical* propulsion seems possible and exotic systems (nuclear, stored radicals) might never get off the drawing board.

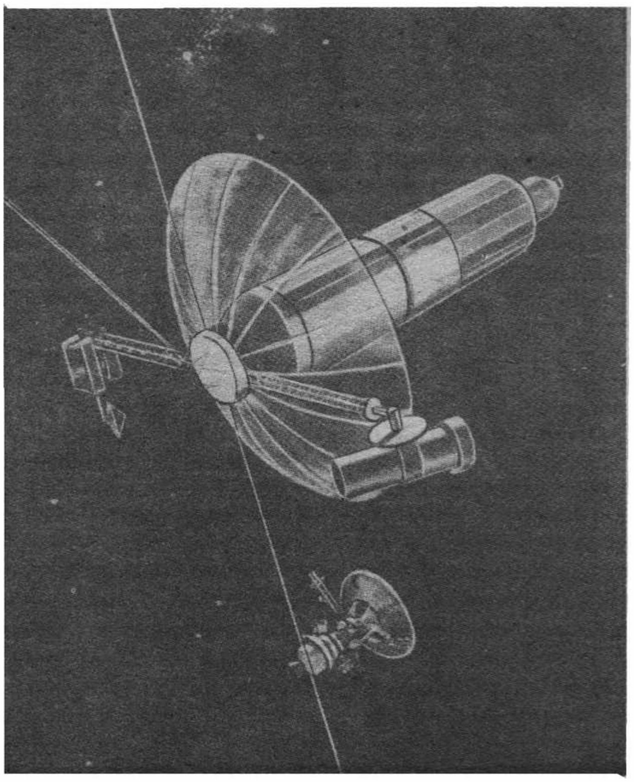
I still recall an illustration in an early science fiction magazine entitled "The Midnight Mail Leaves for Mars." In this electronic age, the very concept has a delightful Pony Express ring about it; but even more fanciful was the midnight mail's point of departure. The artist showed a huge rocket leaping skywards from what could have been a Twentyfirst Century Manhattan. New Yorkers would have to get used to living without windows.

We might never need more than a very few spaceports on this planet, perhaps three or four ranged along the Equator, or possibly on artificial islands. They could be located so that takeoffs weren't a nuisance to the general public though the sonic booms of atmospheric re-entry could annoy a substantial percentage of the human race. The dumping of huge quantities of exhaust products in the upper atmosphere might also prove an environmental hazard.

But what levels of *physical* space transportation will we ever really need? Analogies between astronautics and aeronautics are valuable but treacherous. There were thousands of paying passengers 50 years after Lindbergh, high above the Atlantic at any given moment. Will there be thousands between Earth and Moon, or Earth and Mars? Even on this planet there are now powerful forces eroding the need for transportation, by increasing our ability to communicate with ever-more sophisticated means.

No one doubts that we have the tools needed for the exploration of the Solar System by both manned and unmanned vehicles. When we will use them is dictated more by politics and economics than by technology. But will we ever do more with our neighbours in space than pay them occasional visits and set up automatic research stations there, very much as we have done in the polar regions or on the ocean floor? I doubt it, for so long as we have nothing better than rockets burning chemical propellants to haul us out of that gravitational pit.

However, I am nervous about negative predictions. One



An interstellar probe of the future.

highly relevant here is a forecast made by a leading British aeronautical engineer. In 1929, he laid down the *ultimate* limits of performance for commercial airplanes, when they'd reached technological maturity, as:

Speed: 130 miles an hour

Range: 600 miles

Payload: 4 tons

Total weight: 20 tons.

It is important to realise that the vast improvement - by a factor of ten or more in each case! - was not the result of any revolutionary new invention or discovery. Conventional aircraft had shown otherwise, even before the jet engine came along. In the same way, 50 years or so of advances in materials and engine design could produce rocket-driven spacecraft that would astonish us today - even though they would contain no elements that weren't already perfectly familiar to us.

When the atomic bomb and the V-2 rocket burst almost simultaneously upon the stage of history, many of us hoped that nuclear energy would soon provide propulsion as well as - alas - a payload. Indeed, a billion dollars was spent on the design and testing of atomic rockets before it was decided that there was no operational requirement for them. Indeed, fission reactions, with their problems of shielding and radioactive contamination, do not seem a very attractive line of development.

Nevertheless, they inspired one of the most remarkable 'Visions of Space' ever imagined. Back in 1958 - only one year after Sputnik! - a group of American engineers decided that the only economical way of travelling around the Solar System was by sitting on a pile of small atom bombs and letting them off one by one. Their motto was 'Saturn by 1970.' The story of Project Orion appears in Freeman Dyson's marvellous autobiography *Disturbing the Universe*.

When planning *2001*, Stanley Kubrick obtained the recently declassified reports of the project for we thought of using nuclear-pulse spacecraft in the movie. But the only relic of our flirtation with Project Orion is the name of the shuttle that takes Dr. Heywood Floyd up to the space station.

This daring concept still remains fascinating as a 'thought experiment' because even though it never materialised, it pointed out one way in which really massive payloads - not tons, but *thousands* of tons - could be sent racing around the Solar System. I liked to dramatise the potential of nuclear power by saying that the energy in one H Bomb could carry the entire US Navy to Mars. The problem, of course, was to do it in the right number of pieces.

Thought experiments are essential because they have to precede all real ones. Orion may be revived one day, using low powered fusion reactions, perhaps triggered by pulsed lasers. This may open up the Solar System but we will probably still need to get well out into space first before we can operate the system, to avoid dumping tritium and other nastinesses into the Earth's atmosphere.

Another 'thought experiment' for which I have a soft spot is the lunar launcher, which I proposed in 1950. The Earth's high escape velocity and dense atmosphere make ground-based launch systems impractical - though perhaps modifications of today's carrier catapults might be useful assists to horizontal takeoff spacecraft. The airless Moon, with an escape velocity only a fifth of Earth's, is the ideal location for such a device. The lunar launcher would be a weightless propulsion system with all the advantages of a street car (tram) over an automobile that has to carry its own fuel. We could get payloads into space - from the Moon, anyway - by electrical energy alone. Whether this will ever be worth doing (and we have to get there first!) only the future will tell. It might be, if we could manufacture rocket propellants on the Moon and launch them into refuelling orbits - a proposition which now seems unlikely, as the Moon has lost most of its low atomic weight elements.

Few visions of space are more glamorous or have attracted more public interest than the concept of vast orbiting colonies or aritificial worlds. Although they were first conceived, like most of the other ideas in astronautics, by the Russian pioneer Tsiolkovski, their real godfather was the British physicist J.D. Bernal. In a truly astonishing book, *The World, the Flesh and the Devil*, first published in 1929, Bernal pointed out the advantages of life in a zero-gravity environment and envisaged the time when the human race would become space-faring.

Sooner or later, he pointed out, some of these space colonies would attempt to escape from the Solar System on millenium-long journeys to the stars. To quote: 'This would require a self-sacrifice and a perfection of educational method that we could hardly demand at the present. However, once acclimatized to space living, it is unlikely that man will stop until he has roamed over and colonised most of the sidereal Universe, or that even this will be the end. Man will not ultimately be content to be parasitic on the stars but will invade them and organise them for his own purposes.'

When I met Bernal 20 years later, I urged him to reissue this book. He did, 20 years later still.

The concept of the multi-generation interstellar ark - or 'Worldship,' to use its current name - is one that has attracted countless science-fiction writers, who have developed almost every possible variation on the theme. Our planet, 'Spaceship Earth,' has demonstrated that stable communities can travel between the stars for

hundreds of millions of years; will we be able to do the same thing on a slightly smaller scale but at a considerably greater speed?

Are We Alone?

It seems virtually certain that a civilisaation only a few centuries in advance of our own could perform such feats, if it had the motivation. This raises the whole subject of SETI (Search for Extraterrestrial Intelligence), which I propose to explore only gingerly.

To repeat Fermi's famous question: Where *are* they?

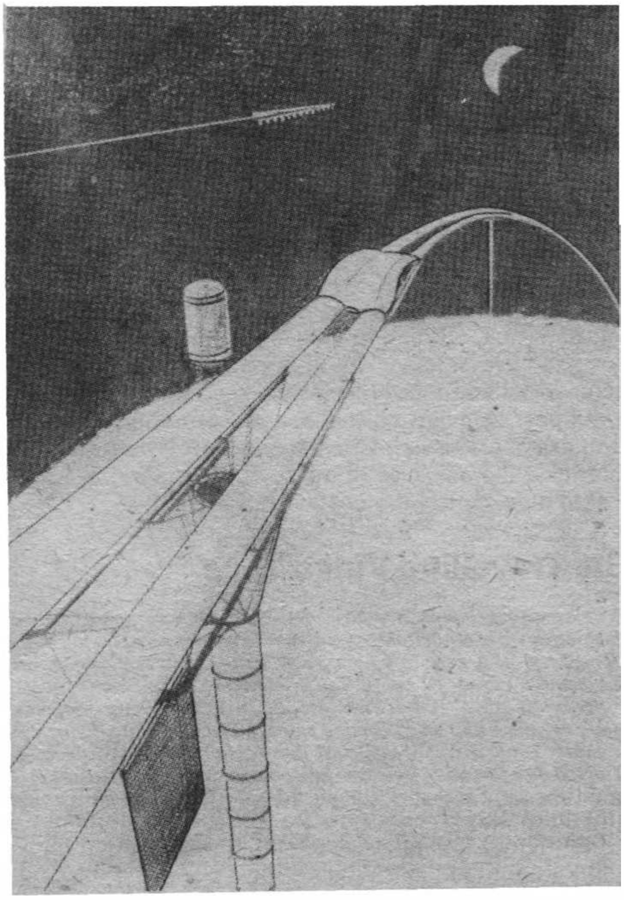
An increasing number of scientists think that they aren't anywhere - in other words, that the human race is alone in the Cosmos - or at least the Galaxy. If this is correct, we'll never be able to prove it; so perhaps it should be ruled out of order as a scientific hypothesis...

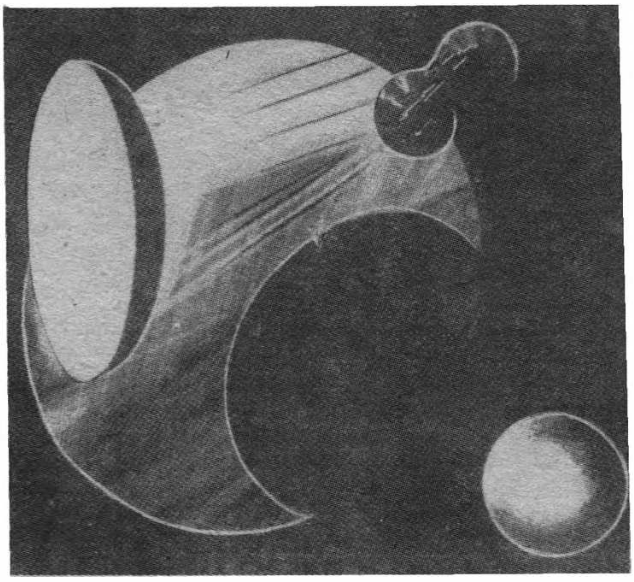
If they do exist, we have a choice of explanations to account for their absence. Here are a few, in no particular order:

1. The Galaxy is so big that they haven't found us yet.
2. They were here a few million years ago and realised that there was not point in hanging around. (The *2001* hypothesis).
3. They know all about us and couldn't care less.
4. We are in a Zoo, and there are strict regulations against Feeding the Animals. (The Quarantine hypothesis).
5. Interstellar travel is impossible.

And so on...

An artist's impression of an Orbital Ring System in polar orbit.





Really big telescopes in space will extend baselines right across the Solar System.

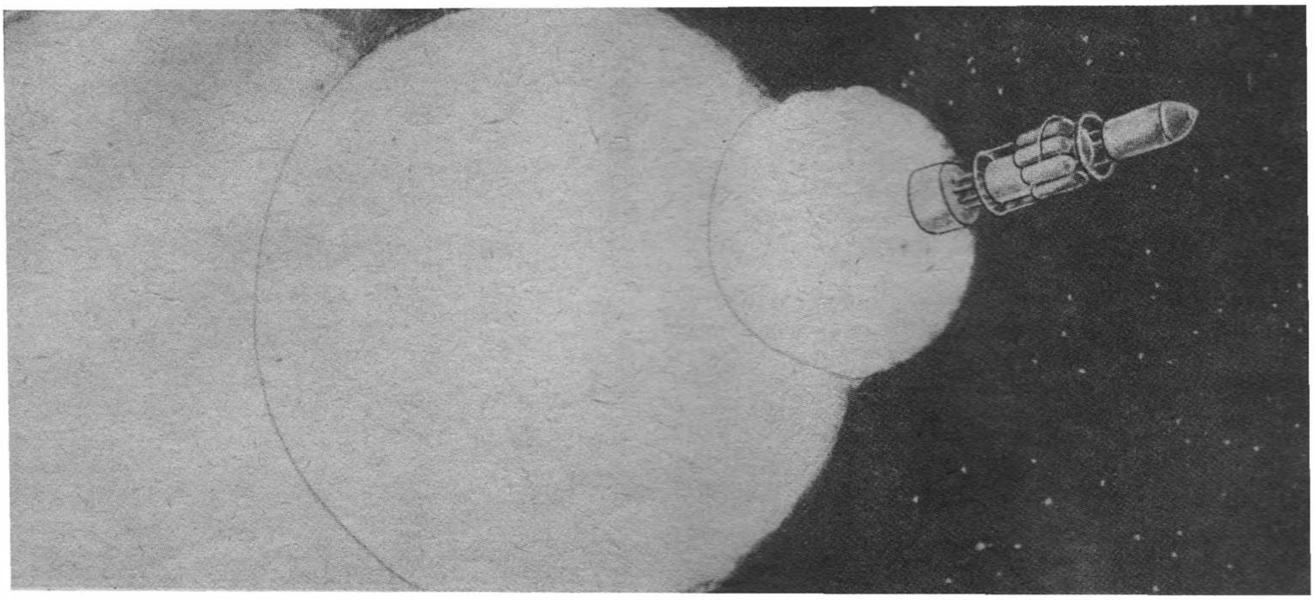
Now, even if interstellar travel is impossible - which I do not believe - it has no relevance to SETI. We should be able to detect extraterrestrial civilisations on their home ground by techniques that we can already envisage. The search for radio emissions - deliberate or accidental - has now been going on for a couple of decades but with such limited resources that success could have come only through a stroke of luck. With really big telescopes in space and by extending baselines right across the Solar System, it should be possible to develop astronomical holography to give detailed images of any planets that exist in this section of the Galaxy.

Of course, we may already possess ample proof of the existence of superior civilisations, yet be too stupid to realise it. Consider, for example, SS433, the most extraordinary object in the entire sky. It beams out two narrowly focussed jets of plasma at a quarter of the speed of light. Astronomers talk about black holes - their usual line of retreat when confronted with the incomprehensible - but I'm scared that SS433 is somebody's Strategic Defense Initiative. A more cheeful alternative is that some cosmic equivalent of CERN has got funding for a really big nuclear accelerator or, a most appalling thought, could SS433 be merely a child's discarded toy...?

We should seek evidence of cosmic engineering. As long ago as 1948, in a Halley lecture at Oxford which must have stunned his audience, Fritz Zwicky remarked: 'We might just as well visualise cold-bloodedly, since it appears inevitable, the reconstruction of the Universe... In the wake of... large-scale nuclear fusion there will, no doubt, follow plans for making the planetary bodies habitable by changing them intrinsically and by changing their positions relative to the Sun.' Other ridiculous ideas mentioned in Professor Zwicky's 1948 lecture were neutron stars and gravitational lenses.

The first modest step that the human race might take towards redesigning the Universe could be the building of the space elevator. It is now a quarter of a century since the Leningrad engineer, Yuri Artsutanov, asked himself if any possible material could bridge - and I use that word deliberately - the gap between the Earth's equator and a stationary satellite 22,000 miles above it. He was surprised and excited to find that the answer is 'Yes.' There is now a vast literature on the subject.

Like the nuclear-pulse 'Orion' concept, the space elev-



Orion Nuclear Pulsejet interstellar spacecraft.

ator may always remain a 'thought experiment.' Nevertheless, even a theoretical demonstration that one can escape from the Earth by using about ten dollar's worth of electricity is psychologically encouraging.

A young English engineer, Paul Birch, has taken the concept of the space elevator even further in the Journal of the British Interplanetary Society (September 1982, March 1983 and June 1983). It is not difficult to visualise the static, equator-to-stationary-orbit structures. What is surprising is that, in theory, one can construct a space elevator from any point on the Earth, to any altitude, as long as it's above the atmosphere! Imagine a space elevator up to the two hour orbit, a mere thousand or so miles high.

One builds a continuous ring around the equator at that altitude, revolving at the required orbital speed of 16,000 mph. Then one constructs a railroad track on it, and set a trolley running backwards along its underside at precisely orbital speed, so that it remains over the same spot on the equator. The next step is to lower a Skyhook to the ground, and one's in business. Of course, if the trolley jumps the rails at its steady cruising speed of 16,000 mph, the result might be embarrassing.

Buckminster Fuller thought of this idea back in 1951, as he pointed out in the sleeve-notes he very kindly wrote to my *Fountains of Paradise* recording. By strange coincidence, an almost identical scene is depicted in the volume by Cosmonaut Alexei Leonov, *The Stars are Waiting.* When Alexei gave it to me in 1968, I never even noticed that he had a space elevator hovering over Ceylon...

No vision of space, alas, can now be complete without some reference to its military uses. After reading what seem like a few million words on the subject, I feel that what the Strategic Defense Initiative needs is a few years of benign neglect while those concerned do some very careful cost-accounting.

Here, I regret to say, honesty compels me to be critical of the film *Star Wars.* I do this with considerable reluctance - even with a sense of guilt. We have already met Darth Vadar, and he is us. If we are to survive, we must exorcise the demons of our haunted childhood and grow out of our fascination with 'technoporn' - gleaming weaponry and beautiful explosions. Whatever new arrangements may be needed to preserve peace in the immediate future, only political solutions can save us in the long run. (If we deserve to be saved. Perhaps a species that has accumulated four tons of explosive *per capita* has already demonstrated its biological unfitness to continue).

There have been times and cultures in which it was unthinkable, and unwise, for a gentleman to appear in public without a weapon. In civilised societies, that need has passed. What now applies to individuals must one day apply also to nations who, after all, are only collections of individuals.

In the very short run we must become intelligent mammals, not turn ourselves back into armoured dinosaurs. It's hard to love people who, for excellent reasons - we dislike - but the alternative is far worse.

Whether we shall be setting forth into a Universe which is still unbearably empty, or one which is already full of life, is a riddle which the coming centuries will unfold. Those who described the first landing on the Moon as Man's greatest adventure are right; but how great that adventure will really be we may not know for a thousand years.

It is not merely an adventure of the body but of the mind and spirit. No-one can say where it will end. We may discover that our place in the Universe is humble indeed; we should not shrink from the knowledge if it turns out that we are far nearer the apes than the angels.

Even if true, a future of infinite promise lies ahead. We may yet have a splendid and inspiring role to play on a stage wider and more marvellous than ever dreamed of in the past. It might be that the old astrologers had the truth exactly reversed, when they believed that the stars controlled the destinies of men.

Men may control the destinies of stars.

The Travelling Video Tape

This essay is the result of an invitation to address the MIT Club of Washington. Unfortunately the trip had to be cancelled owing to the after-effects of a year in which I was involved in five books, one movie and a 13 part TV series – all in my spare time.

Realising that I can no longer risk accepting overseas engagements – and also disliking travel more and more intensely – I therefore made a videotape of my Washington address, to be followed by a phone-in question and answer period. This essay is an edited transcript of that videotape, the copyright of which is vested in the Arthur Clarke Foundation of the United States.

From now on, I hope it will do all my travelling for me.

Arthur C. Clarke

PLANETARY SURFACE TRANSPORT SYSTEMS

by Dr. Harry Joyce

The Moon and planets will one day be inhabited with settled communities and the need will arise for fast, efficient means of transporting goods and passengers. Surface transport systems that are independent of supplies of expendable rocket propellants can be provided by the complementary technologies of Magnetic Levitation and Electromagnetic Vehicle Propulson. A more detailed account of the application of these technologies appears in the September 1985 issue of the Journal of the British Interplanetary Society.

Introduction

One day a network of human habitations will exist on the Moon. Plans for lunar colonisation detailing potential benefits to science and industry from the wide variety of scientific, industrial and other activities that could usefully be carried out there already exist. Such activities will include astronomy, cosmological studies, mining of lunar minerals and the development of industrial processes.

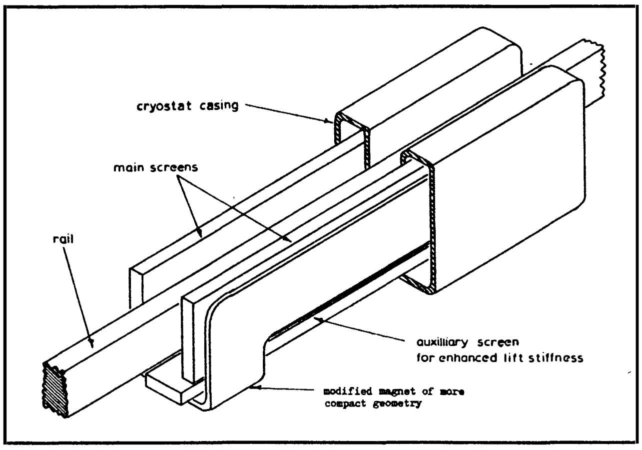
As human activity proliferates over the lunar surface a need will arise for fast, efficient means of transporting goods and passengers. Transport systems able to take reasonably high levels of traffic would, ideally, be independent of expendable propellants, i.e. they would be electrically powered. Two complementary technologies, magnetic levitation and electromagnetic vehicle propulsion, might provide the solution to these needs.

Much research work has been done into the development of levitated vehicles using electromagnetic propulsion for terrestrial transport applications. Apart from their high speed other potential advantages in a lunar application would include high energy efficiency, high reliability, low system maintenance and operation from wholly electrical power sources.

Mixed-Mu Magnetic Levitation

Of the known magnetic levitation techniques, the recently reported technology of Mixed-Mu Magnetic Levitation (which uses superconducting high-field magnets and screens of superconducting material to stabilise the magnetic lifting forces on a steel track) gives a number of important technical advantages over comparable systems.

Fig. 1. Conceptual Mixed-Mu vehicle levitation unit.



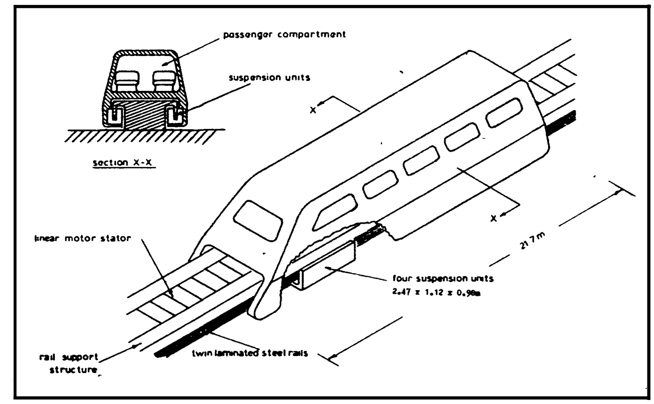


Fig. 2. A high speed Mixed-Mu vehicle.

The track structure for a Mixed-Mu levitated vehicle could be built from ferromagnetic materials available on or near the lunar surface. The power requirements for the system are low and the levitation effect is available at all vehicle speeds, including at rest.

The Mixed-Mu Levitation principle is based on the diamagnetic property of superconducting materials, *viz* their exclusion of magnetic fields (the Meissner effect). An important practical consequence of this is the existence of a repulsive force between a superconducting surface and a source of magnetic field nearby. This repulsive force can be used to stabilise the forces of attraction between a magnet and an iron body. Thus, by appropriate design, the magnetic force and the gravitational forces can be made to balance to produce free stable levitation. The name 'Mixed-Mu' derives from the use of both diamagnetic and ferromagnetic materials in the system (magnetic permeability = μ, or 'mu').

Although natural diamagnetic materials exist, the stabilising forces that can be produced are so weak as to be of no use in such systems. Practical Mixed-Mu systems use the strong diamagnetism of superconductors to produce the stabilising effects.

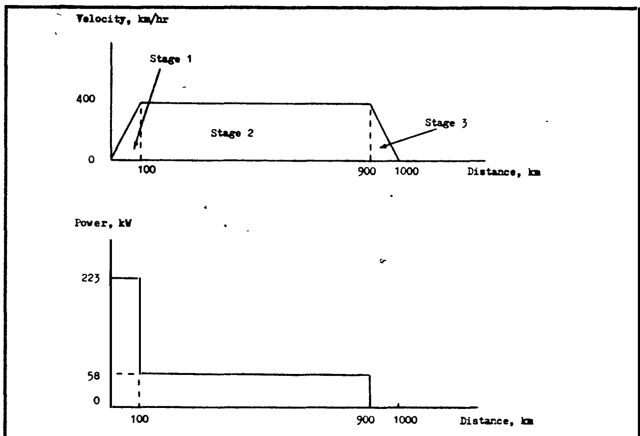
In a vehicle suspension system the movable part of the system is the assembly of superconducting magnets and stabilising superconducting surfaces (known as screens). This levitation assembly is attached to the vehicle. The 'iron body' is a steel rail (part of the track) and of course is fixed.

Levitated Transport Systems

Results of experiments and computational analysis carried out, at the University College of North Wales and at the Rutherford Appleton Laboratory, to prove the effectiveness of the Mixed-Mu principle as a practicable levitation technology have led to the conceptual design for a vehicle levitation unit shown in Fig. 1. The Mixed-Mu levitation unit, consisting of superconducting magnet and stabilising superconducting screens, all contained in a cryostat housing to maintain near-absolute zero temperatures, 'hangs' beneath the steel rail. Clearance gaps are produced by the action of the screens.

Two distinct areas of application of Mixed-Mu Levitation to Lunar Surface transport systems can be forseen. The first is in long distance transport, above 100 km. Here a large, 100 passenger vehicle travelling at up to 400 km/hr is projected.

The second application is in medium speed 'urban' transport, where flexibility of operation as well as reliability and fast turn-around are the major requirements. Here a smaller (25 passenger or goods equivalent) vehicle travelling at around 80 km/hr is a suitable design goal.



Power Requirements:

	Stage 1	Stage 2	Stage 3
Propulsion	205kW	40kW	Regenerative Braking employed
Levitation	10kW	10kW	
Vehicle Systems	8kW	8kW	
Totals	223kW	58kW	0

Total energy requirement for journey = 818MJ

Fig. 3. Velocity and power profiles for 1000 km journey.

A High Speed Transport System

An impression of a high speed Mixed-Mu levitated vehicle system is shown in Fig. 2. The 400 km/hr, 7.5 tonne payload (100 passengers or equivalent) vehicle uses four levitation units acting upon twin ferromagnetic rails. These rails could be of a sintered iron construction, using iron extracted from lunar ores. The rail support structure, which could be fabricated similarly largely from lunar materials, also supports the stator segment of the linear motor propulsion system. The Mixed-Mu suspension system provides lift at all speeds and the low temperature (4 K with presently available superconducting materials but 10 to 20 K based on projected technology within the next few decades) conditions required by the on-board levitation units is maintained by a small on-board refrigeration plant. Electrical power for propulsion and other vehicle systems is provided from on-board rechargable storage elements.

The total mass of the vehicle, including its 100 passengers, is estimated at about 36 tonnes. The approximate dimensions of the levitation unit required for such a vehicle can be derived using scaling laws developed with the help of Dr. G.M. Asher of the University College of North Wales.

The total vehicle electrical power requirement comprises power for propulsion, on-board levitation system and other vehicle systems, including life support systems.

The power requirement for propulsion, in the form of a linear motor system of either the single-sided linear induction motor or linear synchronous motor type can be estimated by considering a 'typical' journey of 1000 km, the velocity profile for which is shown in Fig. 3. The first stage is one of constant acceleration from rest to the cruising speed of 400 km/hr. The second is one of constant velocity. The third is one of constant deceleration to rest at the destination. No power input is required during the third stage as regenerative braking (using the braking of the vehicle to generate electrical power) is used. The total power profile for the 1000 km journey is also shown in Fig. 3. The total estimated energy requirement for this journey is 818 MJ.

Very significant economic and technical advantages may be gained using only on-board energy storage rather than *en route* power collection (pickup). One promising means of energy storage is inductive storage using superconducting coils. An alternative would be storage batteries. It is important to note that, due to the absence of aerodynamic losses on the Moon, the total power requirement for this vehicle is only about 5% of the power required on Earth. A very similar situation would apply, for example, on Mars. Energy density targets for electric vehicle batteries are currently around 140 Whr/kg. The requirement for the 1000 km journey might thus be met from a bank of advanced batteries of total mass about 1000 kg (Storage batteries presently have the drawback of requiring long recharging times).

A Medium Speed Transport System

A medium speed 'Urban Transport' vehicle, designed to carry 25 passengers at speeds of up to 100 km/hr, is shown in Fig. 4. The vehicle, which has an estimated all-up mass of 12.5 tonnes, uses four Mixed-Mu levitation units operating on a twin-rail track constructed similarly to that for the high speed system. Again, the propulsion system would use linear motor technology with a track-mounted stator segment. For the medium speed vehicle power collection is practicable, so minimising on-board power conditioning equipment and obviating on-board energy storage requirements. A projected mean power budget for short journeys with modest accelerations is shown below (kW):

propulsion	95
levitation	5
vehicle systems	4
total on-board power requirement	104 kW

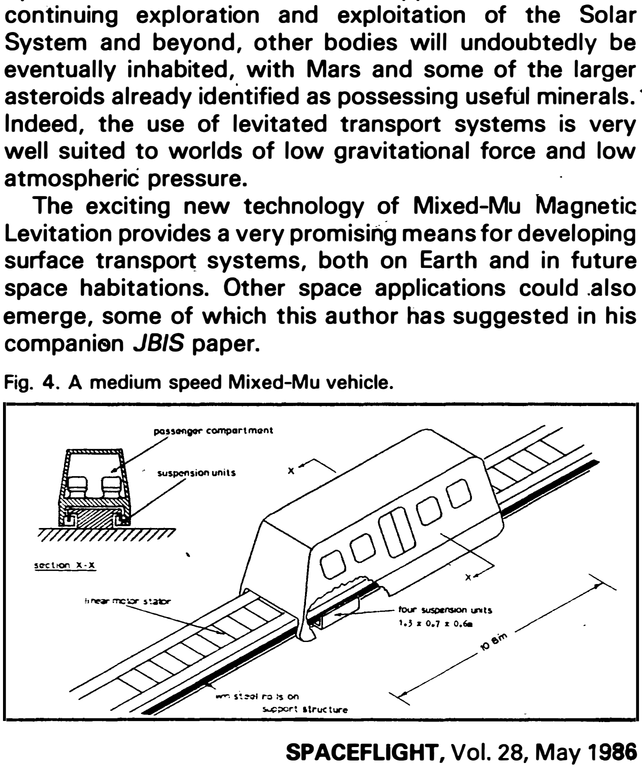
This power requirement could be supplied easily to the vehicle by power collection provision requiring only present day technology. Alternatively, the on-board energy storage approach described earlier could be implemented with only a small increase in overall vehicle mass.

Areas of Application

The use of Mixed-Mu Levitation in surface transport systems is not confined to lunar applications. With the continuing exploration and exploitation of the Solar System and beyond, other bodies will undoubtedly be eventually inhabited, with Mars and some of the larger asteroids already identified as possessing useful minerals. Indeed, the use of levitated transport systems is very well suited to worlds of low gravitational force and low atmospheric pressure.

The exciting new technology of Mixed-Mu Magnetic Levitation provides a very promising means for developing surface transport systems, both on Earth and in future space habitations. Other space applications could also emerge, some of which this author has suggested in his companion *JBIS* paper.

Fig. 4. A medium speed Mixed-Mu vehicle.



More Missions to Explore the Solar System

by J. R. French

The next two decades offer a substantial variety of planned and potential missions for the Jet Propulsion Laboratory. While the impact of the Challenger accident and the resultant grounding of the Shuttle fleet and loss of capacity has yet to be fully assessed, it is probable that the currently planned missions will be carried out generally as described although there will be delays, at least in the near term.

Funded Missions and Programmes

Three launches were planned for 1986 on the Shuttle of which all have already been officially postponed. The ESA Ulysses mission and the US Galileo were both scheduled for launch using the Shuttle with Centaur G upper stage in May. These missions have been rescheduled for the next Jupiter launch opportunity in mid-1987. Since Challenger was one of the two Shuttles equipped to carry Centaur, an additional Orbiter (Discovery) will be modified for this purpose.

Galileo, the NASA mission to orbit Jupiter and probe its atmosphere, has already been extensively discussed in ***Spaceflight*** and will not be described further in this article.

Ulysses, the ESA mission which uses a close flyby of Jupiter to bend its orbit out of the ecliptic and over the poles of the Sun will also be familiar to regular readers of ***Spaceflight***. Why discuss an ESA spacecraft in an article on JPL missions? The mission is an excellent example of international cooperation. Not only are JPL scientists involved in the Ulysses experiments but JPL's Deep Space Network has responsibility for tracking and data acquisition. Data reduction and analysis will be performed at JPL.

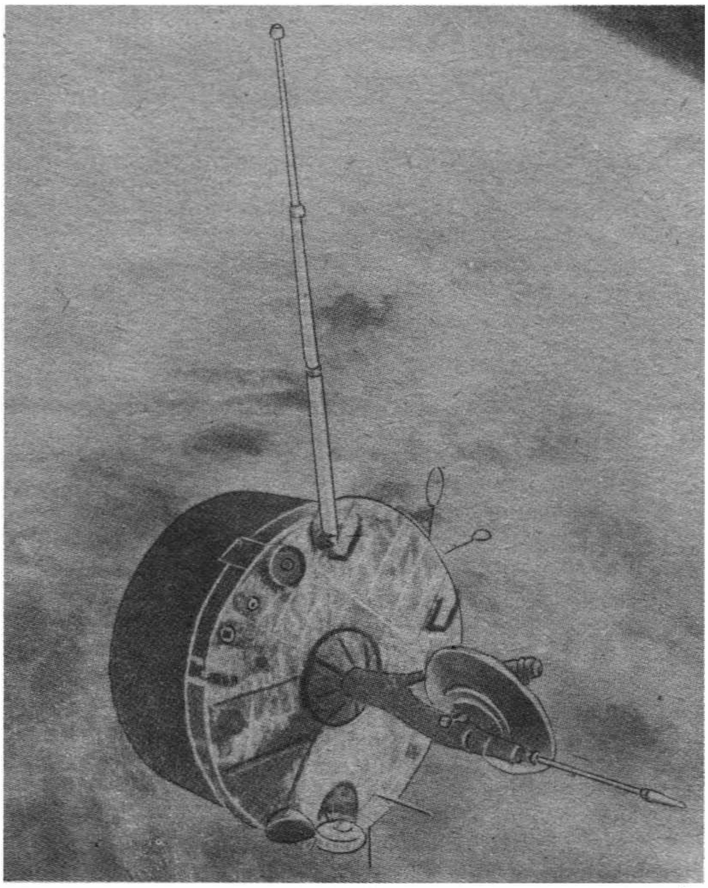
Finally, Ulysses will assist Galileo by evaluating the Jupiter radiation environment to aid in final targeting for Galileo. This is possible because although launched at almost the same time, the much lighter Ulysses reaches Jupiter in about 14 months compared to three years for Galileo. This rapid flight time implies that Ulysses may have the highest Earth departure velocity of any vehicle yet launched.

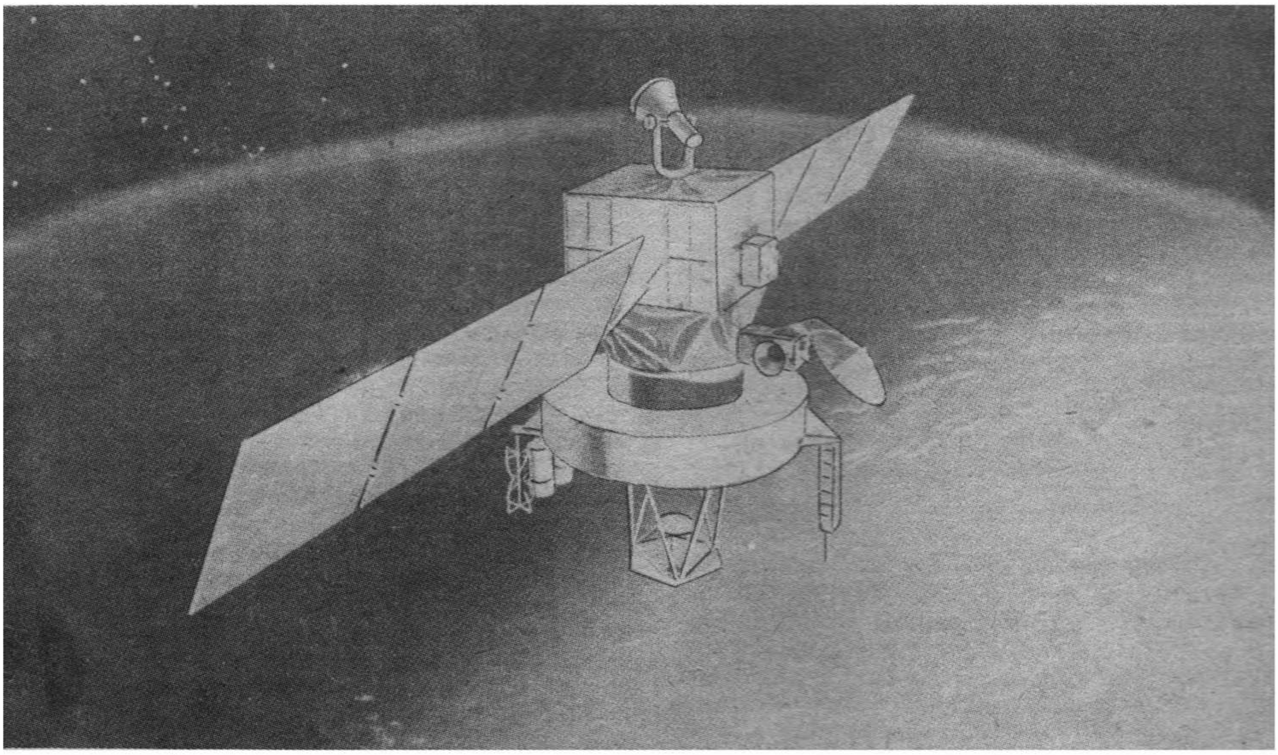
The third near term mission impacted by the Shuttle grounding is the Hubble Space Telescope. This fascinating instrument was originally scheduled for launch in the third quarter of 1986. Again, JPL does not have prime responsibility for the HST as a whole. NASA's Marshall Space Flight Center has overall management of the HST project with the Goddard Space Flight Center responsible for the science instruments and for the Space Telescope Science Institute at The John Hopkins University. JPL's role in the project is to provide one of the instruments which will use the light gathered by the telescope for scientific purposes. The Wide Field/Planetary Camera package consists of two camera systems of different focal lengths (four individual cameras per system) which share the same structure and electronics. The spectral response of the two cameras ranges from the near infrared to the ultraviolet. Twelve filter wheels carrying 48 filters and polarisers, can be rotated into the light path of the cameras to obtain spectral data.

The Wide Field Camera will be used for wide area coverage such as star surveys and detection of sources in particular wavelengths. The Planetary Camera (PC) is a narrow angle, high-resolution device. Each picture element can resolve objects to 0.043 arcseconds, equivalent to seeing a baseball (about 10 cm diameter) at 200 miles (325 km). The PC will be used for high resolution study of the surfaces and atmospheres (if any) of a variety of Solar System bodies. It also will be applied to the study of galaxies, protostars and novas, and to the discovery of Jupiter-size planets orbiting other stars by observing disturbances of the motion of the star.

Even though smaller than the largest Earth-based telescopes, the HST will have enormously greater capacity than any other telescope because it will not have to operate through the atmosphere. The HST should be able to resolve objects 15×10^9 light years distant compared to 2×10^9 light years for the best Earth-based resolution. If the estimate of 20×10^9 years

An artist's impression of the Pioneer/Venus spacecraft in orbit around Venus. Its successor, Magellan, will use imaging radar to further our knowledge about the planet.





The Topex spacecraft will use radar to measure height variations in the sea surface.

for the age of the universe is accurate, then HST will allow us to see three-quarters of the way back to the beginning of time.

Another planned mission is a re-flight of the Shuttle Imaging Radar-B (SIR-B). This mission, a follow on to the earlier Seasat and SIR-A missions, was flown in 1984. However, a faulty communications antenna severely restricted the data return, yielding 16 hours of data covering 15×10^6 square km against a planned 50 hours covering 50×10^6 square km. SIR-B uses a rectangular planar array antenna which is deployed on orbit. The antenna measure 10.7 by 2.1 metres when deployed. By applying synthetic aperture radar techniques the system can build up images with resolution as good as 25 metres independent of clouds, vegetation etc.

A fascinating aspect of radar mapping is that the radar will actually penetrate to considerable depth through very dry soil as in the Sahara Desert revealing ancient waterways and other features now engulfed by the sands. Similarly, much has been learned concerning ancient Central American civilisations by peering through the dense foilage covering those regions. Since radar reflects differently at different angles, observations at different angles of incidence reveals information regarding surface roughness.

Like its predecessors, SIR-B operates at 1.28 GHz (L-band). SIR-C, a proposed 1988 follow-on, would use both L-band and C-band and different polarisations.

Turning again to the planets, 1988 will see the launch of the Magellan spacecraft, an application of imaging radar to exploration of Venus. The dense, cloudy atmosphere of Venus has precluded detailed study of its surface. Pioneer-Venus with its radar altimeter has provided some idea of the large scale topography and a Soviet radar mission has provided additional data. Magellan (formerly called Venus Radar Mapper) will map nearly 90 per cent of the surface at a resolution of 1 km, about equal to the Mariner 9 photographic map of Mars. The spacecraft makes extensive use of spare parts from Viking, Voyager and Galileo programmes in order to reduce cost. Magellan will be placed in an elliptical 3.1 hour orbit about Venus. During each orbit, the radar will operate during the 40 minutes when the spacecraft is nearest the planet and the data, after substantial on-board processing and compression, will be transmitted back to Earth during the remainder of the orbit. Total operation in Venus orbit will be about eight months. The imaging radar will be supplemented by a radar altimeter accurate to 100 metres.

In 1990, the US will again turn toward Mars with the Mars Observer (MO) mission. MO will be placed in a low circular area polar orbit designed to cause the spacecraft to cross a given spot on the equator at the same time each day (9 am or 3 pm). The spacecraft will carry a suite of instruments dedicated to composition measurement. In a full Martian year (two Earth years) of operation the spacecraft will observe the planet and its atmosphere in great detail determining composition, amount and distribution of condensed volatiles (such as water) on the surface, and study the interaction of atmosphere and surface. MO is of additional interest in that it represents the first time that a spacecraft designed for Earth orbit use will be modified for use at another planet.

It is hoped that MO will be the first of a series of missions, the Moon and near-Earth asteroids being identified as other targets. The payloads would of course be modified reflecting the lack of atmosphere but the detailed surface constituent mapping, of vital interest not only for science but for future utilisation, remains much the same.

Near Term Planned Missions

Beyond Mars Observer, we leave the realm of projects actually approved and in progress and enter

the world of pre-project development and advanced study. Next in line is TOPEX, the name deriving from Ocean Topography Experiment.

TOPEX is an Earth observation mission and again makes extensive use of radar. In this case a radar altimeter will be used to measure height variations in the sea surface. The variations in question are not those due to wave motion but large scale deviations from the mythical "sea level" caused by currents, eddies, and other circulation features as well as by sea floor geological structures. No other observational means can provide the global view of these factors which are vital to understanding ocean circulation and the detailed geology of the sea floor.

In order for altitude data to be useful it is necessary to know the location of the spacecraft to a high degree of accuracy at all times. To this end, special radio and laser tracking systems will locate the satellite to an accuracy of 13 cm. A 1330 km orbit has been chosen to minimise atmospheric drag and a 63 degree inclination will provide coverage of most of the world's oceans.

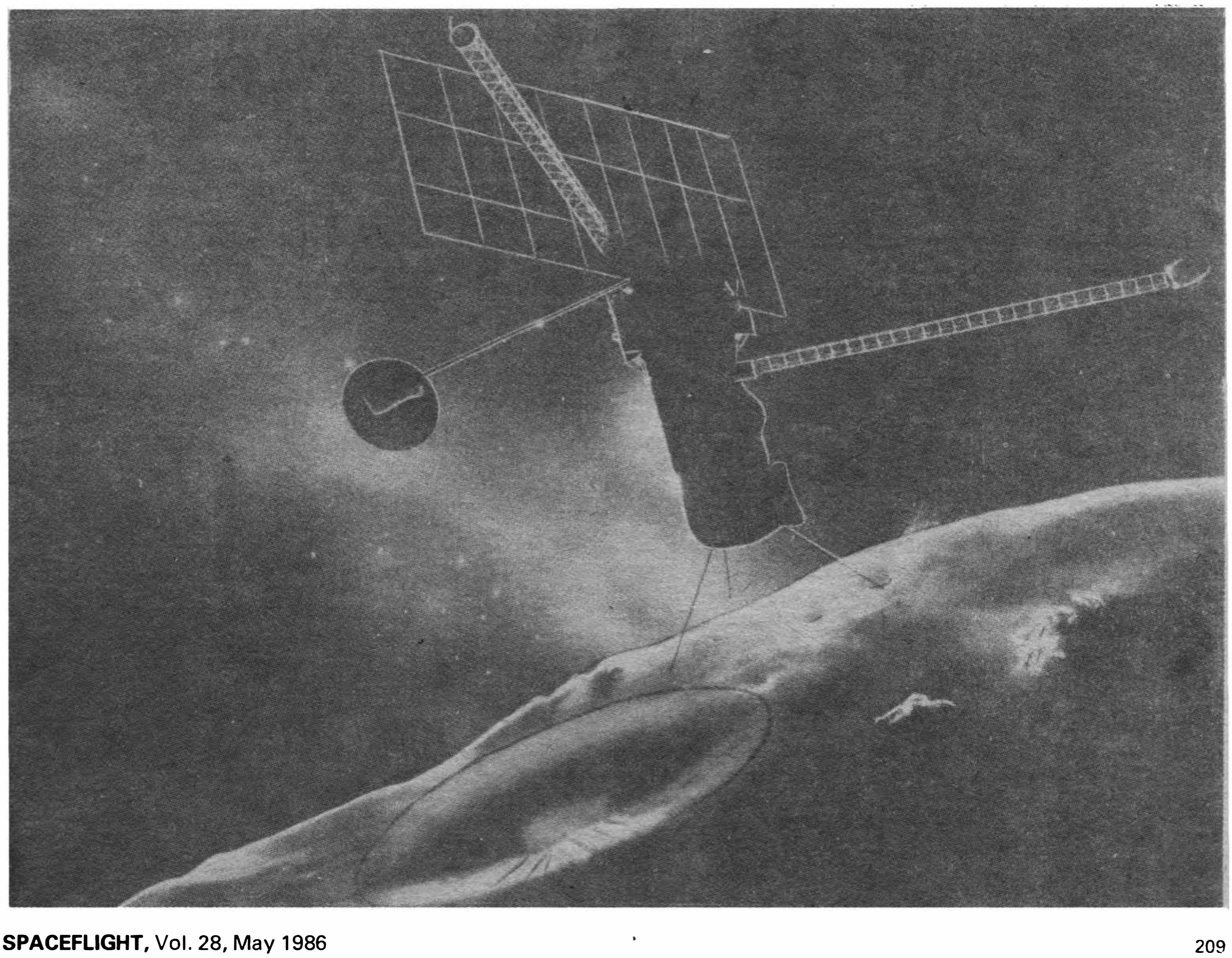
TOPEX is an international effort. The French National Center for Space Studies (CNES) had planned a similar mission called Poseidon. The two missions have now been combined with a French experimental altimeter and another instrument being accommodated on the American spacecraft which will be launched aboard Ariane. The TOPEX project is targeted for an official start in Fiscal Year 1987 and launch in the early 1990s.

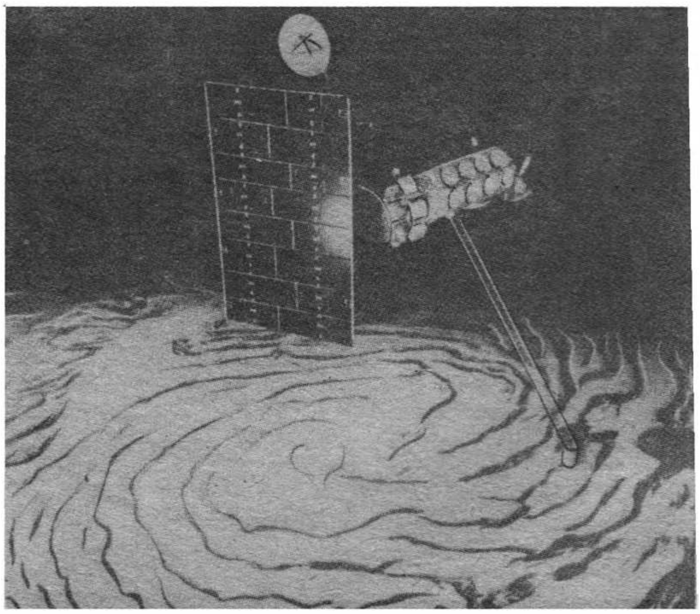
The next deep space mission in the new start queue is the Comet Rendezvous Asteroid Flyby (CRAF) mission. This mission represents the front of a new series of spacecraft called Mariner MkII. This series was originally conceived as an attempt to reduce cost by limiting the spacecraft to a relatively small set of instruments and maintaining a high level of inheretance from one mission to the next, characteristic of the highly successful early Mariners. However, as the concept has evolved the first characteristic has been left behind: CRAF will carry a substantial suite of instruments. The second remains in force. CRAF subsystems are being designed with future missions in mind.

The CRAF mission will rendezvous with a short period comet such as Tempel 2, Kopff or Wild 2. The rendezvous will occur near aphelion (most distant point from the Sun) of the comet orbit. This distance typically is about five Astronomical Units (1 AU is the Earth's distance from the Sun) for the comets in question. Since the outbound trajectory will traverse the asteroid belt, most missions will have the opportunity to fly fairly close to at least one asteroid. In addition to visible imaging cameras, CRAF will carry composition measuring instruments and instruments for studying radiation and magnetic fields. Two scan platforms will be mounted, one for very accurate pointing of precision instruments, the other for instruments requiring less accuracy. CRAF may carry a penetrator to be fired into the comet. The spacecraft will follow the comet as it approaches perihelion and becomes active.

The Mariner Mk IIs will be designed for missions in

A mission to rendezvous with an asteroid.





The Mars Observer.

the outer Solar System as far as 30 AU from the Sun. A probable next mission mission after CRAF is a Saturn orbiter. One possibility is a radar equipped orbiter which, while studying Saturn with other instruments, would use the radar to map Titan in repeated flybys. The current favourite is a Saturn orbiter with a probe to be sent into the dense nitrogen-rich atmosphere of Titan. A cooperative version of this mission, called Cassini, is being jointly studied by NASA and ESA. Possible other missions include a mainbelt asteroid flyby and orbiters or flybys of Venus, Neptune, and Pluto.

Future Plans

Ambitious missions to further our exploration of Mars are being studied for the mid-to-late 1990's. Studies of robotics, which have a variety of possible applications on Earth also offer the capabilities of sending a highly autonomous surface roving vehicle to Mars. Such a vehicle, limited by the power of its Radioisotope Thermoelectric Generator (RTG) could move only very slowly but, like the tortoise of the ancient fable, by persistant effort could cover a substantial distance. Depending upon time spent travelling versus time spent stationary performing observations or obtaining samples, such a rover might cover 100 km or more in several months of operations.

Unlike the highly intelligent, independent robot of science fiction, this robot would require a good deal of help from its human creators. A typical traverse scenario would proceed as follows: The rover, on command, would take a panorama of stereo images concentrating in the region of proposed direction of travel. The operator on Earth would study the stereo images and select a route consisting of as many as three straight path segments through the nearby obstacle field. The length of the path segments, from a few metres to many tens of metres depends mostly on local terrain roughness and obstacle density, in other words the distance the operator be reasonably sure of a safe, clear route.

The path data are then sent to the rover which proceeds to navigate them by dead reckoning using an odometer and gyro compass. Under study is the possibility that the rover could enhance its navigational accuracy by "correlation tracking", imaging various objects as it travels and comparing the perceived location with the predicted; very much what a human being does in navigation by landmark on Earth.

To be effective, the rover would require significant manipulation capability. Research is in progress on advanced manipulator concepts at JPL, and Johnson Space Center is sponsoring work on sample acquisition techniques.

The rover could operate as a stand alone mission exploring, performing detailed sample analysis and returning the data to Earth. A rover could also function as part of a sample return mission. In this mode the on-board analysis capability would be reduced in favour of sample selection and sample site documentation.

The return of selected sample from Mars has long been a major goal of planetary science. While much can be done in-situ, much more can be accomplished in certain specific areas (e.g. age-dating) than could be done with in-situ instrumentation. A further argument is that the full power of all Earth's science laboratories can be brought to bear rather than the limited capability of one spacecraft. As new investigative technology becomes available it can be applied to the samples in hand immediately avoiding the necessity of developing a flight qualified instrument using the new technique and mounting a new mission to deliver it; such a mission being subject to the usual vagaries of the selection and funding approval cycle.

A sample return mission is complex and fairly demanding in the context of today's technology. It is however quite possible and has been under serious study for a number of years. A variety of mission concepts have been studied. In brief, the options involve whether the lander enters the atmosphere of Mars directly or goes first into orbit. If it does go into orbit first is this accomplished with propulsion or with aerodynamic braking? Upon departing Mars does the sample carrier procede directly to Earth or simply go into Mars orbit where a dedicted return vehicle acquires the sample for the return journey? Because of Earth launch limitations, the options combining aerodynamic capture at Mars and/or direct entry for the lander with rendezvous in Mars orbit as the return mode are most favourable since they tend to require the lowest mass departing Earth orbit. Other fascinating concepts such as manufacturing all or part of the propellant for the return from Martian resources are under study but are viewed as more speculative at the moment. The earliest date for launch of a Mars Sample Return mission is generally felt to be 1996.

Summary

The concepts presented above are those viewed as the leading contenders for JPL activities in the next 15 years. If most or all of these missions are carried out this will be another period of great progress in the understanding of our Solar System. While budgetary problems and shifting national and international politics are unpredictable in their effects, it appears that there is a good chance for maintaining a healthy planetary science programme in the next few years. There is certainly no lack of things to do.

The work upon which this article is based was conducted at the Jet Propulsion Laboratory, California Institute of Tecnology, under contract with the National Aeronautics and Space Administration. James R. French was a member of the Spacecraft Design and Engineering Section at JPL. He has recently joined the American Rocket Co. as chief engineer.

25 YEARS ON

Prospects For International Cooperation

by Gennady Zhukov

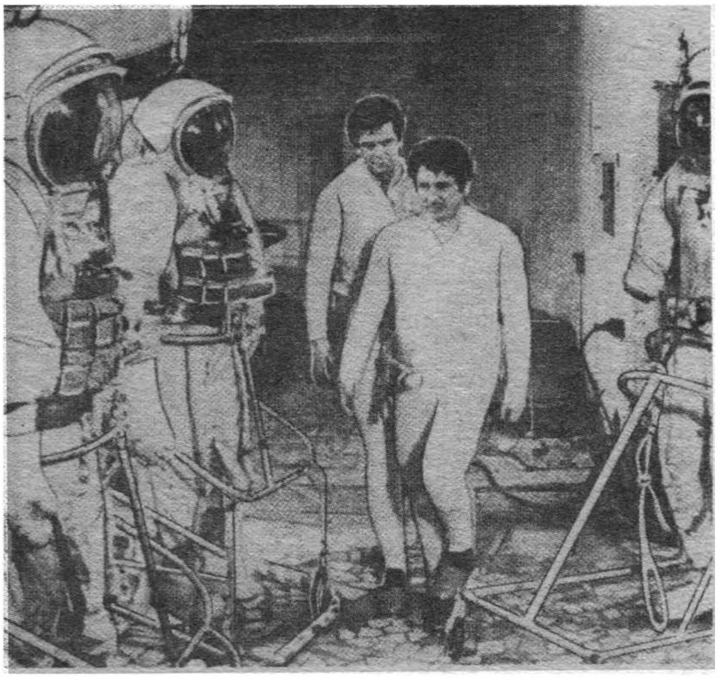
A quarter of a century ago Yuri Gagarin soared into Space for what now seems a short, albeit history-making mission of 108 minutes duration. In near-Earth space, in the not so distant future, we should see permanent orbital stations belonging to different countries with passenger and transport vehicles shuttling between them and the Earth. Soviet Salyut (1971) and Mir (1986) spacecraft are widely regarded as crucial landmarks on the way towards man's continued presence in Space. After operating Skylab, launched in 1973, the US decided in 1984 to build a permanent station in Space within the next ten years. In Western Europe, members of the European Space Agency, as well as Canada and Japan, indicated they were willing to join forces with the US in such an enterprise.

In some fields, practical uses of manned space flight have already emerged. Space photography and observation to monitor the Earth's surface is one such field and it seems that one day it will be possible to monitor natural resources and the environment on a global scale.

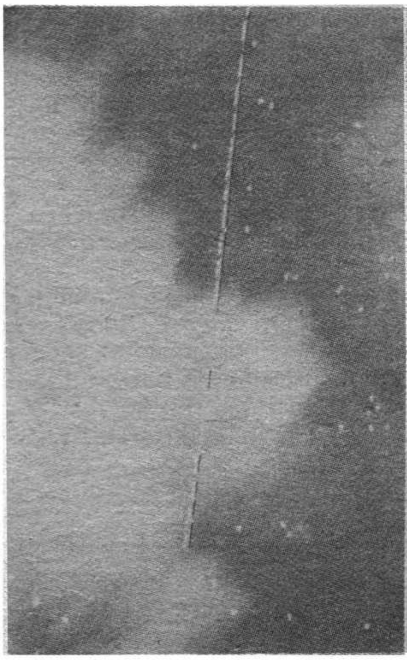
Another major economic benefit offered by manned Space flight is the opportunity to develop new Space technologies. Already hundreds of experiments have been carried out onboard orbital spacecraft to produce new materials in zero gravity. A semi-industrial facility codenamed 'Korund' was operated onboard Salyut-7 to manufacture semiconductors with properties hardly attainable on Earth.

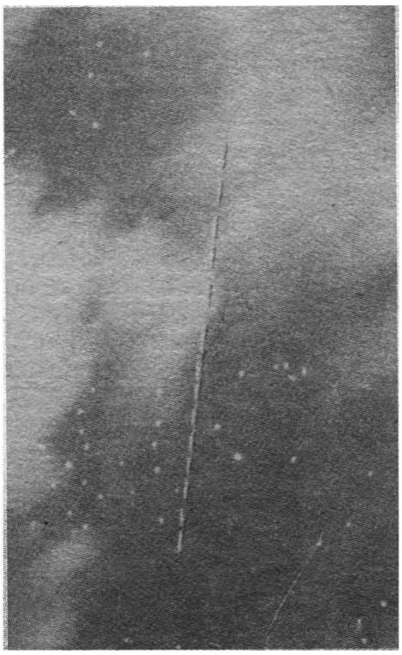
The results achieved so far indicate that many industrial Space facilities will be set up in the future. Assembly work carried out by Soviet cosmonauts in Salyut-6 and Salyut-7 spacecraft showed convincingly that big structures, such as mammoth radio telescopes or solar electric power sources could, indeed, be built in space.

The Soviet-American Soyuz-Apollo mission and joint flights by Soviet cosmonauts and researcher-cosmonauts from Czechoslovakia, Poland, the German Democratic Republic, Bulgaria, Hungary, Vietnam, Cuba, Mongolia, Rumania, France and India proved that international Space missions were a reality. In 1983 a US Shuttle spacecraft carried its first international crew.



Cosmonauts Leonid Kizim and Vladimir Solovyov are pictured at the Yuri Gagarin Cosmonaut Training Centre before blast-off in March. The cosmonauts have since been testing the Mir space station's onboard systems and spending their free time reading and listening to news on the radio.





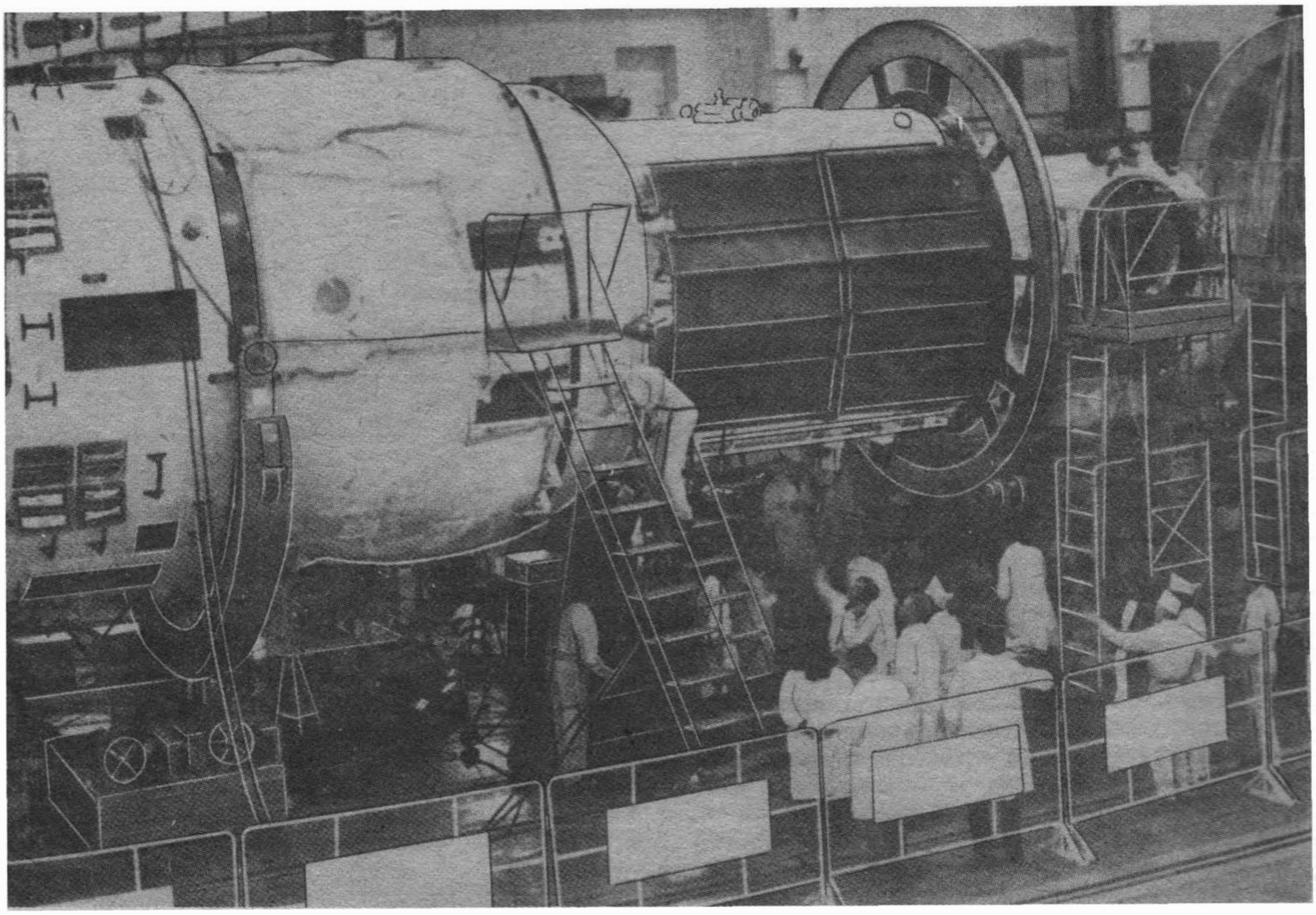
Space Stations In Close Earth Orbits

On 7 March, Salyut 7 and the Mir Space Station were photographed by BIS member Armin Cordil at Trier, W. Germany, moving from west to east through the upper part of the constellation Orion.

The two photographs were taken only 45 seconds apart and illustrate the close proximity of the two space stations along the same orbital track. Identification is based on NASA predictions.

The trail of Salyut 7 appears in the left-hand photograph and that of Mir is the right-hand one taken some 45 seconds later. The exposures were interrupted every second. (Ilford HP5, 1:1.4/50). The three stars of the Orion Belt are readily identified.

SOVIET SCENE



A mock-up of the new Soviet Space Station, Mir, under inspection by scientists and engineers.

Under United Nations sponsorship two international conferences on the Exploration and Peaceful Uses of Outer Space were held in Vienna in 1968 and 1982. An array of measures have been mapped out to translate the recommendations of these conferences into reality, and a UN programme to use space technologies has been endorsed. At the 40th Jubilee Session of the UN General Assembly the USSR tabled a programme for mutually advantageous international cooperation in the peaceful uses of outer space, including a proposal to set up an international space organisation. Many countries see such cooperation as a key to resolving the energy, raw materials and other major problems facing mankind.

International institutions already exist that are increasingly promoting international cooperation in the peaceful uses of Space. During a rather short period of time, six such institutions have been set up to deal with different aspects of Space exploration. These include Intelsat (The International Telecommunications Satellite Organisation), Intersputnik (an international telecommunications system based on the use of artificial satellites), Inmarsat (The International Organisation for Maritime Communications by Satellite), Arabsat, Eurosat and the European Space Agency. Never before has international cooperation known anything like this. Even commercial organisations involved with Space exploration have emerged. These run Space-launch facilities of their own. Rendering services to clients on a commercial basis and paying up to 14 per cent interest to investors. The international programme for space exploration known as Intercosmos is another particular form of cooperation in the peaceful uses of space as also is the Cospas-Sarsat system.

In 1966, on the fifth anniversary of the first manned Space mission, Yuri Gagarin quoted Konstantin Tsiolkovsky, the Father of Cosmonautics, as saying that Space exploration will become a powerful tool and added, "we are convinced that this is what will happen and that space must be used to safeguard peace".

Analysis of Halley Data and Pictures

Scientists from nine countries have been busy analysing 12,000 pictures and other data received from Vega 1 and Vega 2 as the two space probes passed within a few thousand kilometres of the nucleus of Halley's comet.

On March 6 Vega 1 passed through the gas and dust layer shrouding the comet to come within 9,000 km of its nucleus. Three days later on March 9, Vega 2 passed even closer to the heart of the comet, coasting along at just 8,200 km from the nucleus.

Despite having been bombarded by fine particles of matter travelling at 50 km per second, both Vega 1 and Vega 2 were almost undamaged. Vega 1 suffered slight damage to its solar battery panels but was otherwise functioning normally.

Vega 2's closer proximity to the comet's nucleus and the better "weather" it experienced as it passed through the dust and gas layer, meant that the pictures it relayed back to Earth were sharper and clearer than those taken by Vega 1.

Along with their Soviet colleagues, scientists from Austria, Bulgaria, Hungary, the German Democratic Republic, Poland, West Germany, France and Czechoslovakia, are taking part in the Vega project.

An important task of the Vega probes was to take pictures of the comet's nucleus. The craft coped with the task and beamed back to Earth pictures of the comet's head with a resolution of 200 metres. The very first pictures showed the comet was likely to have a double nucleus, but this was later interpreted as a more complex structure than expected.

It took the Vega 1 and its sister craft, Vega 2, launched from Baikonur, well over a year to reach Halley's comet. Last June the two craft used their onboard facilities to conduct a series of experiments in the atmosphere and on the surface of Venus.

From mid-February specialists began preparing the interplanetary probes for the second part of their project. Final adjustment of TV cameras and other equipment, using Jupiter as a reference point, was carried out and during the operation the probes flashed back to Earth colour pictures of the planet taken from a distance of approximately 800 million kilometres.

First pictures of Comet Halley from a distance of 14 million kilometres were taken on March 4. At that time Vega 1 was at a distance of approximately 170 million kilometres from Earth. Television cameras on the Vega 1 observation platform had tracked down the comet, zeroed on it and photographed it through different light filters. Over a 90 minute spell the craft took several dozens of photographs on which the nucleus was seen as a tiny dot.

Twenty-four hours later, Vega 1 halved the distance separating it from the comet and conducted another filming session. All photographs it produced are expected to yield invaluable information about the structure and chemical composition of Halley's comet. Photographs taken when the craft passed close to the nucleus showed the dust cocoon around the nucleus is not as dense as expected. Later tests showed that Vega 1 was bombarded with dust particles but was not damaged with instruments continuing to function.

On March 9, Vega 2 passed within 8,200 kilometres of the nucleus, returning more valuable information.

In total the Vega probes returned nearly 12,000 pictures taken in various fields of the spectrum – from the ultraviolet to the infrared. Detailed study will make it possible to establish the chemical composition of the cometary components.

Dr. Vasili Moroz of the Soviet Academy of Sciences Space Studies Institute said that Halley's comet probably does not have a double nucleus.

"Most probably, the central part of the comet has a complex structure. The nucleus itself is of irregular shape.

"A close study of the photographs makes us believe that there is a single nucleus, although we cannot rule out the possibility of comets made up of two or more bodies," said Dr. Moroz.

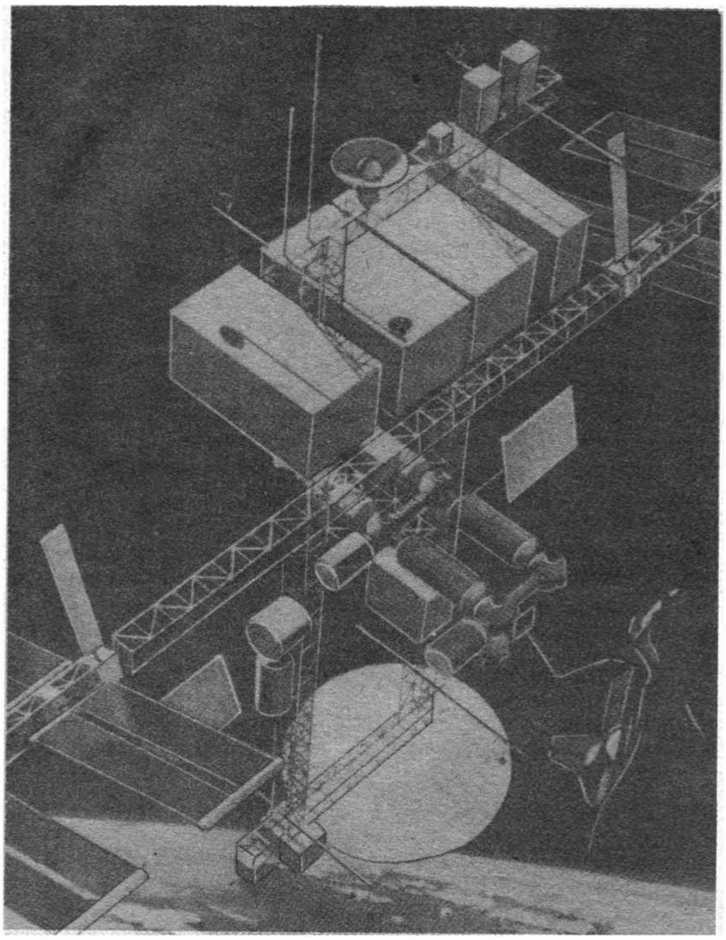
At a press conference on March 10, the director of the Institute of Space Studies of the USSR Academy of Sciences Roald Sagdeyev summed up the main results of the project. He noted that work with the comet was not yet finished and a painstaking analysis of data will now proceed at the research centres and laboratories of the participating countries.

The International Consultative group of space agencies in session on March 5 at the Soviet Academy of Sciences Space Research Institute, studying the first pictures from Vega 1.

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

NASA CONSIDERS CONFIGURATION FOR SPACE STATION



An artist's impression of the newly selected "dual-keel" configuration for the international manned Space Station being serviced by a Space Shuttle. The structure gives more room to mount telescopes and other scientific instruments compared to the previously favoured "power tower" design.

Design and development contracts for the next phase of Space Station development could start within the next 12 months.

Important decisions have already been made, notably the switch from a "power tower" concept in overall design to a "twin keel". The change provides for more structure to mount telescopes and other scientific instruments as well as providing a more stable platform for materials processing work.

Within the next few weeks NASA will also be announcing the initial number of US modules to be accommodated on the Space Station.

Boeing Aerospace is currently working with the Marshall Spaceflight Center on the development of these modules which will be used as habitats and work places for astronauts.

Neutral buoyancy tanks are now being used to simulate Space Station repairs and maintenance tasks which may have to be performed by astronauts during EVAs (see picture below right).

Meanwhile, the European Space Agency (ESA) has failed to notify NASA by a formal deadline in early March of what hardware it plans to study during the second half of the definition and design stage of the Space Station project which lasts until the end of this year.

A problem arose between the two agencies after NASA refused to compromise over its position regarding the European detachable module, saying it could not be incorporated during early operation of the Space Station. Unless resolved this could lead to a situation where NASA proceeds on the basis of having no European hardware in the baseline configuration.

AUTOMATION KEY FOR COLUMBUS

Logica has now begun work with European partners on the Columbus project, part of the international manned Space Station.

EVA RADIO PACKS TO TRANSMIT COLOUR PICTURES

The first advance development equipment for the International Space Station was delivered to NASA'S Johnson Space Center in early March by RCA. Consisting of two extra vehicular activity (EVA) radios, the equipment will be essential for astronauts to maintain communications with the Space Station, scheduled for launch in the 1990s.

NASA will use the equipment for testing and evaluation to ensure that the radio will perform satisfactorily in space. It will also be used by astronauts in simulation.

The final radio pack will be about the size of a shoe box and will operate in Ku-band frequencies. It will be integrated into a multi-access communications system linking the Space Station to the astronauts, the Space Shuttle, satellite factories and laboratories orbiting near the Station, and the orbital transfer and manoeuvring vehicles.

Like the EVA transceivers designed by RCA for the Apollo and Shuttle programmes, these radio packs will transmit and receive voice communications and telemetry. But the Space Station will require a more advanced communication system.

The new EVA pack will also transmit colour television pictures from the astronauts to the Shuttle and the Station for re-transmission to Earth. On a video display panel mounted inside their helmets astronauts will receive data, such as instructions for repairing satellites.

The company was selected to define a number of aspects of Columbus which will be critical to the overall efficiency of the station. Issues being addressed include:

- The overall human factors environment in the Columbus laboratory.
- The automation of as much as possible of the operation of the station.
- Automation of the ground support facilities (currently several thousand people support a Spacelab flight).
- The integrity of the enormous amount of complex software in the station and on the ground.
- The use of artificial intelligence techniques.

Four contracts, the initial phases of which are worth £350,000, have been awarded to Logica by three leading European space companies for:

1. Definition of human factors and software requirements in the manned laboratory (with Aeritalia, Italy).
2. Definition and design work for the data management system of all four elements of Columbus (Matra, France).
3. Definition and design of operations and ground support facilities for the man-tended platform (British Aerospace, UK).
4. Definition of the development work for the data management test bed for use in evaluating Columbus technology (Matra, France).

JAPANESE LABORATORY

NASA and Japan's Science and Technology Agency have reached agreement on hardware elements that Japan will carry into the next phase of the Space Station definition and preliminary design study.

Japan will conduct preliminary design activities on an attached multipurpose research and development laboratory for the remainder of the Phase B period which extends until January 1987.

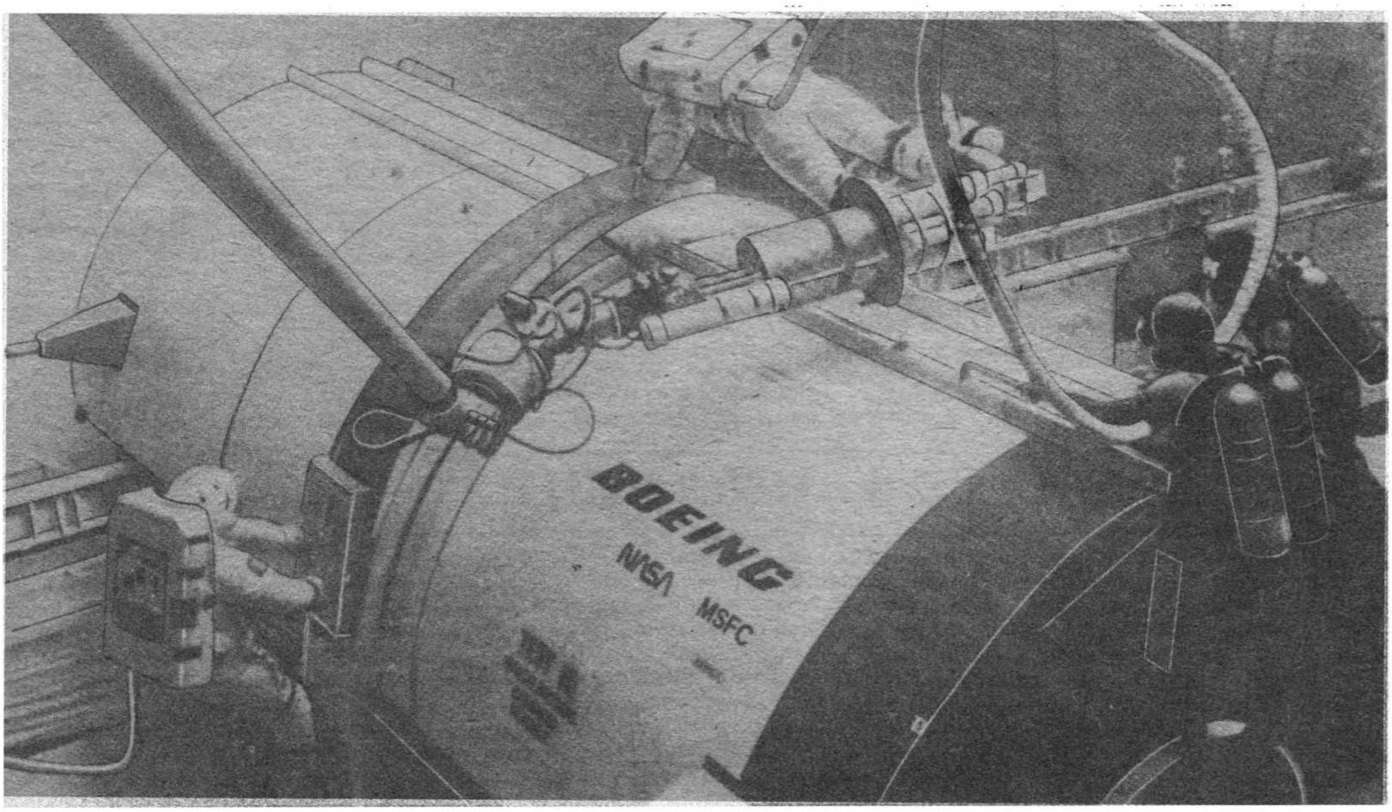
The Japanese hardware includes a pressurised module that will provide shirtsleeve work space for station crews, an exposed work deck, a scientific/equipment airlock, a local remote manipulator arm and an experiment logistics module. The multipurpose laboratory will accommodate general scientific and technology development research, including microgravity research, as well as the control panels for operating the Space Station's mobile remote manipulator system and payloads attached to the station.

This agreement only covers the remainder of the Phase B period and does not obligate Japan to develop this hardware.

NASA has also agreed to a Canadian proposal to perform preliminary design of a Mobile Servicing Centre during the remaining phase of the Space Station definition and preliminary design study.

The Mobile Servicing Centre would be a multipurpose structure equipped with manipulator arms that would be used to help assemble and maintain the Space Station, as well as help upkeep instruments and experiments mounted on the Station's framework.

Although underwater rather than in space, two "astronauts" repair a combination heat radiator and debris shield mounted on a Space Station module mockup in the NASA Marshall Space Flight Centre's Neutral Buoyancy Facility. Boeing Aerospace's Brand Griffin, the "astronaut" shown in centre, is being positioned by a mockup of the Space Shuttle Orbiter's remote manipulator arm. *Boeing*



SATELLITE DIGEST — 192

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

Robert D. Christy

Continued from the April 1986 issue

CHINA 18, 1986-10A, 16526.

Launched: 1240, 1 Feb 1986 from Xichang by Long March 3.
Spacecraft data: Cylinder covered in solar cells, approx 2 m long and 2 m diameter. The mass (excluding fuel) is about 400 kg.
Mission: Chinese national communications satellite.
Orbit: geosynchronous above 103 deg east longitude.

COSMOS 1729, 1986-11A, 16527

Launched: 1811, 1 Feb 1986 from Plesetsk by A-2-e.
Spacecraft data: Probably similar to the Molniya satellites.
Mission: Missile early warning satellite.
Orbit: Initially 628 x 39263 km, 708.41 min, 62.87 deg, then manoeuvred to 632 x 39710 km, 717.52 min, 62.87 deg to ensure daily ground track repeats.

COSMOS 1730, 1986-12A, 16540

Launched: 1115, 4 Feb 1986 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft with spherical re-entry module, instrument unit and a supplementary package of instruments at the forward end. Length about 6 m, diameter (max) 2.4 m, and mass around 6000 kg.
Mission: Military photo-reconnaissance, recovered after 9 days.
Orbit: 194 x 300 km, 89.44 min, 72.86 deg.

COSMOS 1731, 1986-13A, 16589

Launched: 0845, 7 Feb 1986 from Tyuratam by A-2.
Spacecraft data: as Cosmos 1730.
Mission: Military photo-reconnaissance, long duration.
Orbit: 232 x 312 km, 89.7 min, 64.77 deg, manoeuvrable.

USA 15-17, 1986-14D-F, 16623-16625

Launched: 1000, 9 Feb 1986 from Vandenberg AFB by Atlas F.
Spacecraft data: not available.
Mission: Triple launch of radar carrying reconnaissance satellites for the US Navy.
Orbit: 1050 x 1170 km, 107.5 min, 63.4 deg.

COSMOS 1732, 1986-15A, 16593

Launched: 0658, 11 Feb 1986 from Plestsk by F-vehicle.
Spacecraft data: not available.
Mission: Possibly a geodetic satellite.
Orbit: 1480 x 1526 km, 116.09 min, 73.61 deg.

YURI 2B, 1986-16A, 16597

Launched: 0755, 12 Feb 1986 from Tanegashima by N-II.
Spacecraft data: Three-axis stabilised vehicle with a box shaped body, 1.20 x 1.32 x 2.89 m (incl aerials). Power is provided by a solar array of 8.95 m span. The mass is 677 kg, reducing to 307 kg on after apogee boost motor firing and total depletion of attitude control and station keeping propellants.
Mission: Inorbit spare for BS-2A, providing television signals to areas of normally difficult reception within Japan.
Orbit: geosynchronous above 117 deg east, intended for final placement above 100 deg east longitude.

MIR, 1986-17A, 16609.

Launched: 2129*, 19 Feb 1986 from Tyuratam by D-1.
Spacecraft data: Similar to Salyut, being a stepped cylinder, 15 m long and maximum diameter 4.15 m. The mass is around 20 tonnes. Power is provided by a twin panel solar array and MIR is fitted with five docking ports at the forward end, and a single port at the aft end.

Orbit: Initially 172 x 301 km, 89.17 min, 51.62 deg, then manoeuvred to 324 x 340 km, 91.11 min, 51.62 deg for operational use.

COSMOS 1733, 1986-18A, 16611.

Launched: 2305, 19 Feb 1986 from Plesetsk by F vehicle.
Spacecraft data: not available.
Mission: Electronic intelligence gathering.
Orbit: 633 x 662 km, 97.74 min, 82.53 deg.

SPOT 1, 1986-19A, 16613.

Launched: 0145*, 22 Feb 1986 from Kourou by Ariane 1 (V-16).
Spacecraft data: Box shaped body, 2 x 2 x 3.5 m, carring a single 15.6 m solar array at right angles to one end. The mass is 1830 kg incl fuel.
Mission: Remote sensing satellite providing images for commercial distribution.
Orbit: 824 x 829 km, 101.49 min, 98.74 deg, sun-synchronous.

VIKING, 1986-19B, 16614.

Launched: 0145*, 22 Feb 1986 from Kourou by Ariane 1 (V-16), with SPOT 1.
Spacecraft data: Octagonal, tapered cylinder with max diameter 1.8 m and length 0.5 m, the mass is 286 kg.
Mission: Electrical, magnetic and ultraviolet studies of auroral regions.
Orbit: 811 x 13536 km, 261.75 min, 98.83 deg.

COSMOS 1734, 1986-20A, 16618.

Launched: 1340, 26 Feb 1986 from Plesetsk by A-2.
Spacecraft data: as Cosmos 1730.
Mission: Military photo-reconnaissance, long duration.
Orbit: 167 x 345 km, 89.65 min, 67.14 deg, manoeuvrable.

COSMOS 1735, 1986-21A, 16620.

Launched: 0143, 27 Feb 1986 from Tyuratam by F-1.
Spacecraft data: not available.
Mission: Electronic intelligence gathering over ocean areas.
Orbit: 403 x 418 km, 92.79 min, 65.02 deg.

NEW ARIANE LAUNCH SITE

Two communications satellites were successfully placed into geostationary transfer orbits by an Ariane 3 launcher from the new ELA 2 launch site at Kourou, French Guiana, on March 28.

The flight, five weeks after the previous Ariane launch, is regarded as validation of ESA's new launch facilities which will be used for the first Ariane 4 later this year.

First attempt to launch the Ariane V17 mission on March 20 was interrupted during the last seconds of the countdown sequence due to a discrepancy in information about the arming of the third stage cryogenic umbilicals.

The satellites were G-Star 2 for the American GTE Spacenet company, and Brazilsat S2 for Brazilian company Embratel.

NASA Sets Shuttle Launch Budget for 1987

An official statement on the setting of a budget for an assumed restart of the Shuttle programme in 1987 is to be welcomed. It demonstrates confidence in the future of the Shuttle programme – confidence that the technical problems that led to the Challenger disaster can be overcome and confidence that disruption to the programme will in the long-term be minimal.

The budget allows for the first manned launch to be in February 1987 using the Orbiter Atlantis with a further eight launches before the end of 1987 without the inclusion of civilian astronauts. In accordance with earlier reports, the O-ring seals in the boost motor casing have been identified as the source of the trouble and a high-priority programme has been set up to redesign the boost motors.

The Board of Inquiry which is investigating the accident is due to report before the end of May and will make wide-ranging recommendations for improved safety. It is expected to identify organisational weaknesses within NASA and its interface with industry and to call for tighter inspection and authorisation procedures. Implementation of the recommendations will itself take time and skilful direction will be needed to avoid any unnecessary upheaval.

It remains to be seen what depth of reorganisation and change will take place and whether the February 1987 date can be confirmed. In any event, the months ahead should see a stronger NASA and stronger US Space programme emerge.

The new head of the US Space Shuttle programme says the United States will initiate a "robust" Shuttle flying schedule over the next few years that will be as safe as possible.

Richard Truly, NASA's associate administrator for space flight, has told agency employees that the entire management structure, the programme's decision-making processes and every element of the Space Shuttle will be reassessed before clearing another Shuttle flight after the January 28 Challenger disaster.

Truly, who replaced Jesse Moore as Shuttle chief in February, said the first post-Challenger Shuttle flight will lift off in daylight from Kennedy Space Center, Florida, under conservative weather conditions; will have a conservative flight design; and will carry a payload that NASA already has had experience with.

He said the landing would be on the large desert runway at Edwards Air Force Base in California, and not on the shorter concrete runway at Kennedy Space Center. Some astronauts have complained of safety problems in landing Shuttles at Kennedy.

Truly emphasised that no date has been set for the first resumed Shuttle flight and no definite number of flights has been scheduled for the first year. He said an agency plan to resume flights next February and to conduct nine launches in the first year of resumed flight was announced earlier only for budgetary and planning purposes.

"The first thing we must do is to reassess our entire programme management structure and our organisation. The philosophy, the structure, the reporting channels and the decision-making process will be looked at, and those changes implemented if necessary to assure confidence and safety in this programme" said Truly.

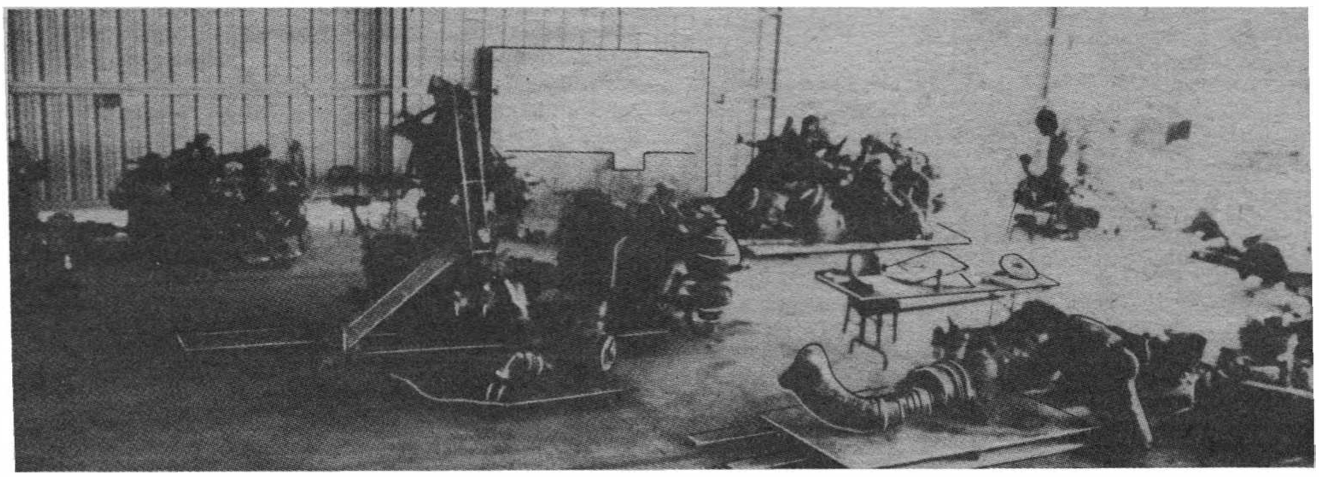
The joint on the Shuttle's solid-fuel rocket booster that is suspected of causing the accident will be redesigned by technical experts from both NASA and outside organisations.

In addition a complete design review of all other elements of the Shuttle system and a total recertification of all items listed as "criticality one" (items whose failure could cause catastrophe for the spacecraft and its crew) will be carried out.

NASA has already released a list of 700 critical Shuttle parts without backup features, including the rubber seals of the Shuttle's rocket boosters.

Truly also stated that the agency would look at abort procedures and philosophy, range safety systems, runway configuration and length, and weather forecasting abilities to assure acceptable margin of safety to the vehicle and crew can be provided.

A large portion of the three main engines of Challenger have been recovered from the floor of the Atlantic Ocean. They are now spread over the floor of a storage building at the Cape.



Inquiry Hears of Booster Concerns

The Presidential Commission inquiring into the loss of Space Shuttle Challenger is due to report during May. Many key points have already been made by witnesses giving evidence at the inquiry and below Spaceflight reproduces actual transcripts of pertinent parts of testimonies from early parts of the hearings.

Allan McDonald (booster rocket manager for Morton Thiokol) was at Kennedy Space Center when the launch occurred.

McDonald: "The weatherman was projecting temperatures as low as 18 degrees Fahrenheit, sometime in the early morning hours of the 28th, and there had been meetings with some of the engineering people who had some concerns about the O-rings (preventive seals used at areas where booster segments are joined) getting to those kinds of temperatures.

"The bottom line was that the engineering people would not recommend a launch below 53 degrees Fahrenheit.

"The basis for that recommendation was primarily our concern with the Discovery launch that had occurred about a year earlier in January 1985... and that particular loader (booster) had a couple of field joints that not only had some erosion but they had some fairly severe blow-by (escape of rocket exhaust gases).

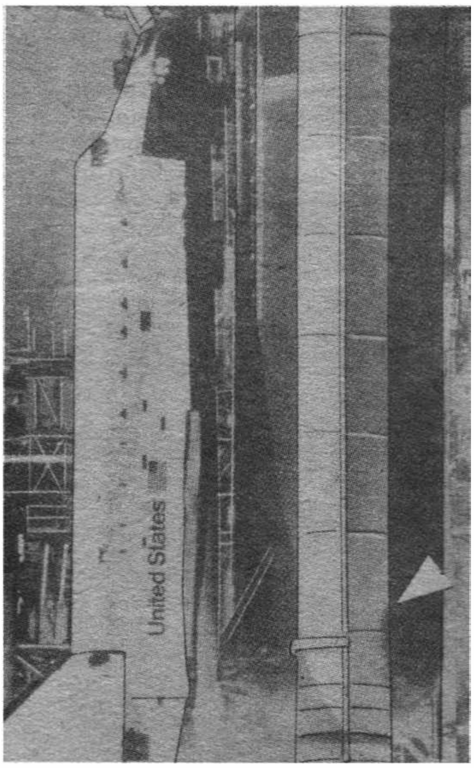
"Because of that, we were concerned of launching beyond our experience base, below that temperataure.

"I commented at the time that I felt that lower temperatures were in the direction of badness for both O-rings, because it slows down the timing function for both of those, but the effect is much worse for the primary O-rings, compared to the secondary O-ring.

"We knew that the cold temperature shrank the O-ring some, and our resiliency tests, which are tests that basically show how the O-ring responds when you have it under some compression and release that load, showed that as it gets cold and stiff it doesn't want to respond very well.

"Based on the controversy relative to how conclusive the effects of temperature actually were on this phenomena, we were asked to reassess and re-evaluate that data, and we decided we would do that.

"At that point the recommendation was not to launch below 53 degrees."



Space Shuttle Challenger at the moment of lift-off. A puff of black smoke can be seen emitting from the lower portion of the SRB (arrowed).

During an eve of launch tele-conference McDonald said he believed Joe Kilminster (a Morton Thiokol official) came on the line and said that even though we had some concerns about the lower temperatures, that we would recommend they proceed with the launch based on the fact that we felt that the temperature data that we had was not totally conclusive.

McDonald: "He outlined several concerns, still, that we had relative to the effect of temperatures but also some rationales to why we felt it was safe to proceed.

"I didn't see anything that I recognised that was new information, but maybe they had some. I felt that all the engineers were certainly there that had generated the original data, evaluating it, and maybe they had reconsidered or re-evaluated the data they had... and felt it was probably OK.

"He was asked, I believe it was by Mr. Hardy, I'm not sure, to put that rationale in writing and to sign it. Make sure they get it down to the Cape, I think by morning, early morning.

"I was sitting across the table from Larry Mulloy and I said that I felt that I was the one who was going to have to sign it, because I was at the Cape, and I said I wouldn't sign that.

"I told them I didn't feel very good about this recommendation.

"I was absolutely surprised that NASA would accept any recommendation below 40 degrees Fahrenheit, especially with a predicted temperature as low as 26 degrees Fahrenheit.

"In fact, I made the direct statement that if anything happened to this launch, I told them I sure wouldn't want to be the person that had to stand in front of a board of inquiry to explain why a launch was outside of the qualification of the solid rocket motor or any Shuttle system.

"When I made that statement, no one commented on that."

"I was still very upset, so I asked that they reconsider this decision for three reasons, not one, for three.

"First one being the concern of the cold O-rings that we had just discussed. And there were two others.

"The booster recovery ships were in an absolute survival mode... they were in seas that were as high

as 30 feet, there were winds at 50 knots (58 mph) sustained, gusting to 70 knots (80.5 mph), pitching the boats as much as 30 degrees.

"They even felt the rough seas may have damaged some of the retrieval equipment at the back of a ship.

"There was no way they would be able to support an early morning launch.

"I then reminded everyone in the room that, you know, there were some firsts on this launch. This is the first time we're going to use a new electronic control system or separating the nozzle extension cone on the SRBs at apogee rather than just before water impact.

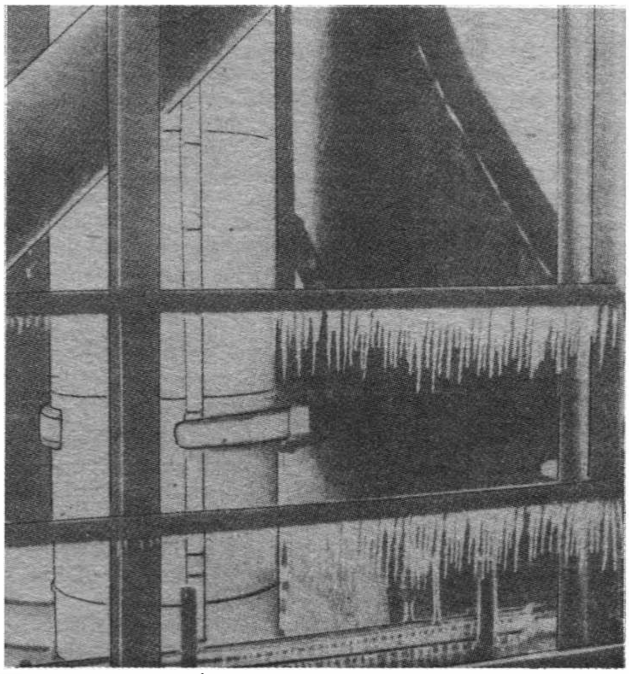
"Based on the sea states that I had just heard, it appeared to me it was going to be nearly impossible to recover that hardware. I also said that the third reason for not launching was the formation of ice.

"I didn't think it was prudent to launch under that kind of a condition."

Rocco Petrone (president of Rockwell Space Transportation): "I first heard about an ice concern at about 4 o'clock (a.m.) Pacific Standard Time. At that time I got on the phone with my two program managers. They described what they knew in Florida. We drew the following conclusions: ice on the mobile launcher itself that could be falling would be debris. We were very concerned with debris of any kind at the time of launch. What happens to that ice when you light your liquid fuel engines would it throw it around and ricochet and potentially hit the Orbiter?

"We had not launched in conditions of that nature and we felt we had an unknown. I then called my two program managers at 5.45 and said we cannot recommend launch from here. I said 'Let's make sure that they in NASA understand that we at Rockwell feel it is not safe to launch.'"

Robert Glaysher (Rockwell vice-president for Orbiter systems): "There was a major unknown in evaluation of the ice aspiration effects ice that would ricochet from the fixed service structure and head towards the vehicle, and ice that was resting on the mobile launcher platform at engine ignition. This was the first time this had occurred. We therefore felt that since we were in an unknown condition and were unable to predict where the ice would go or the degree of damage that would result, I said that Rockwell cannot 100 per cent assure that it is safe to fly, which I quickly changed to Rockwell cannot assure that it is safe to fly."



This picture shows the overnight built-up of ice on the launch gantry prior to lift-off of mission 51L.

Glaysher was then asked if he thought he had made it clear launch was not being approved because of a safety aspect.

Glaysher: "Yes, we actually discussed our position that I had stated more than once during the meeting, Rockwell's position that we could not assure that it was safe to fly."

Notebook From The Cape

by Gordon L. Harris

Not since the glory of Apollo has Kennedy Space Center been in the news forefront for weeks – this time because of Challenger's fiery death Jan. 28. As a kind of climax to weeks of tragedy, the Presidential Commission investigating the worse space disaster conducted day-long interviews of NASA witnesses March 7. About 300 tourists and more than 100 media personnel attended the proceedings held in the Galaxy Theatre of "Spaceport USA", the grandiose title of the former Visitors Information Center.

★ ★ ★

During that same week former astronaut Richard Truly, now a rear admiral, US Navy, was appointed chief of the Space Transportation System Program. And President Reagan named Dr. James Fletcher NASA Administrator, succeeding Dr. William Graham. Fletcher previously held the office from 1972 until 1977. He is the former president, University of Utah, and was a professor at the University of Pittsburgh at the time of his selection. After leaving the agency Fletcher was connected with a new Washington firm which proposed to buy a Shuttle and sell its cargo carrying capacity to commercial users.

★ ★ ★

As the week drew to a close, two other developments kept the Challenger story alive and on front pages. John Young, chief of the astronaut office at Johnson Space Center, who has flown more missions than any other human, sharply criticised his agency for allowing schedule pressure to take priority from flight safety. It was a serious criticism of agency policy from one man whose views carry great weight in Washington and elsewhere.

At almost the same hour when Young's blast became public knowledge, NASA disclosed that divers had located Challenger's crew compartment with "remains" within off the Florida coast in 100 feet of water. Few welcomed the development – some of the surviving members of astronaut families would have preferred that autopsies, funerals and more headlines would never occur.

Path of Progress

Sir, I would like to respond to two very interesting points raised by Mr. J. A. Hartley (Correspondence, March 1986). 1) Would a larger anterior spike give more performance to the STS external tank? 2) Could additional solid rocket boosters enable an Orbiter to be placed in trans-lunar injection?

The spike on Trident missiles and other bodies serves the purpose of baffling the build-up of shock waves in the atmosphere at supersonic speeds. Once the optimum dimensions have been determined, lengthening the spike would serve no further aerodynamic purpose, any more than, say, a man diving into water would find his speed increased by having longer arms.

Regarding fitting extra SRBs to the Shuttle configuration, this raises a number of problems. Granting that all could be filled from the same batch of propellant to avoid density discrepencies, where would the extra rockets be situated? The present arrangement has a tripodal form with two SRBs and main Orbiter engines giving a stable and steerable flight path: introduce other boosters and the tripod symmetry is spoilt, even if they are mounted close to the existing ones, an instability would result. Also the heat profile would soar in the exhaust area, a point which at the present time does not bear dwelling on.

Far better would be increasing the power/size of the existing SRBs and external tank, but this would need to be done in conjunction with parallel development on all other Shuttle systems: it would be a mistake to concentrate on enlarging boosters without carefully examining and developing every other aspect of STS technology, since knowledge is being gained on all systems all the time – witness the design improvements between Columbia and Atlantis and Columbia's recent 18 month refit. We can, I think, see beyond the present period of doubt and uncertainty to a future which has a second generation of Space Shuttle in which both Orbiter and associated systems have significantly advanced capabilities and therein, I submit, lies the surest path of progress.

P. W. MILLS
Chatham, Kent.

Flight to Halleys Comet

Sir, On Saturday January 11, 1986, 205 people (many of them BIS Members and Fellows) boarded a British Airways Boeing 757 and left Heathrow at 17.50 on BA Flight No. 9203C destined for seeing Halley's comet!

The flight was kindly arranged by British Airways Captain D. and Mrs. Jole Johnson who were very ably assisted by an enthusiastic British Airways crew and support staff.

From the start it was obvious that this was going to be something special, for our aircraft had special seating arrangements that allowed maximum movement in the gangways and a good outside view through the windows. A special Comet Champagne Cocktail was served right at the beginning.

This "special" feeling was heightened when we were allocated a separate runway from the main traffic flow and performed a "jump" take off with an initial rate of climb of 6000 ft/minute. This had us firmly glued in our seats until we reached our operating height of approximately 40,000 ft. The aircraft levelled out, we were served a sizeable snack tea, and then settled down to eye accommodation and observation of the night sky and the comet.

We had been placed in a "park and patrol" area which allowed us to cruise at 40,000 ft and around 400-450 knots (ground speed). Under these conditions the Boeing 757 is an exceptionally steady star observing platform. The stability was such that when I was observing Jupiter with a moderate telescope there was no discernable sway or wobble of the image.

All the internal and external lights had been switched off - hence us being parked in a patrol area clear of the commercial airlanes and eye accommodation was very good. Our height and the good visibility was such that we could see whole areas (Portsmouth and the Isle of Wight, Bristol Port, the Severn Bridge etc) all clearly laid out in glittering arrays of sodium and mercury lamps! Only a Shuttle could do better.

And Halley's comet? Yes we saw that too, sometimes by dint of kneeling on the floor and looking upwards to get the reference stars. Some people saw the developing tails, others could only see the main coma and central area. Some had neck ache!

During the whole of the flight we were given a running commentary and expert guidance by Dr. John Mason (Royal Greenwich Observatory). Prior to the flight he had given us a good briefing on the comet and its history and background – an excellent lecture backed up with slides and a video.

The whole flight lasted about 1¾ hours, 1½ of which was good observing time. Many passengers just "came for the ride" and said they wouldn't have worried if they didn't see the comet!

Thank you British Airways and thank you Captain Johnson and all the crew and supporting staff.

You have set a precedent and shown that the Boeing 757 is a very good steady observation platform. If any other good comets should suddenly arrive we would like the opportunity to repeat the experience!

A.T. LAWTON
Shepperton, Middlesex

Docking at the Mir Space Station

Sir, There has been much written of late on the chances of a joint mission between a Shuttle and a Salyut. I agree with a view aired at the last BIS Soviet Space Forum meeting that no such flight will take place due to the fact that the Shuttle Orbiter is so much larger than a Salyut, therefore reducing the propaganda value of such a flight to the Russians to virtually nil. We will see a joint flight only when the new Mir Station (A Salyut by another name . . .) has been joined by more units to make it physically larger – and not before.

MARK BURRELL
Berwick-upon-Tweed

Venus before Mars?

Sir, In my recent letter regarding a Soviet Earth-Venus round trip I had intended to refer to a highly elliptical orbit around Venus (to reduce the energy requirements). This should have been described as an orbit of low eccentricity, not high as stated in the letter.

STUART W. GREENWOOD
Maryland, USA

Cape Correction

Sir, Oh really, what are we coming to, when even the BIS can refer to "Cape Kennedy" (*Spaceflight*, March, Milestones, P.144, item for January 19)? – and when you published a letter from me on the subject some time ago too! The name was changed back to Cape Canaveral – in 1973.

RAY WARD
Sheffield

CORRESPONDENCE

The NASA Budget

Sir, One must sympathise with the concerns of astronauts about safety after the Challenger tragedy. I had always believed in NASA's safety efforts and have been appalled to read details of an accident that seems to have simply been waiting to happen.

But let us not put too much blame on NASA management. Some of the blame goes to penny-pinching administrations that have supported the goals but then have not given the money to do the job. The SRBs themselves were a budgetary compromise. In the 1970s criticisms of delays in getting the Shuttle flying were combined with budget restrictions that made the delay worse.

Financial strictness has stopped being merely annoying and has certainly contributed to disaster. Less money must not mean less safety. Adequate money reduces the temptation to cut close to the margins. I for one would welcome more coverage of the subject of budgets in ***Spaceflight***.

DAVID TUDOR
Coulsdon, Surrey

Ed. *Details of the NASA 1986 budget appear on pp. 248 and 304 of the 1985 volume of* ***Spaceflight.***

Shuttle over Ireland

Sir, M. Kitchener's letter (***Spaceflight***, March 1986) prompts me to tell you of a successful experiment in "sound and vision" Shuttle-watching which we conducted last year.

During the Spacelab 3 mission, the Orbiter passed over Ireland four times in the evening twilight and was clearly visible in the cloudless skies on the four successive nights. In conjuction with the national television network, Radio 2 publicised the times for sighting the Shuttle and announced that we would broadcast the "live" air-to-ground communications during each three-minute pass over the country.

The result was most impressive and generated a great deal of listener reaction. We plan a future simul-cast in which we hope to get a Shuttle crewman or woman to speak directly with our audience as they pass overhead.

My thanks to Paul D. Maley of Rockwell Shuttle Operations Co. in Houston, who did the necessary computer work to allow us make Shuttle sighting predictions for Ireland.

LEO ENRIGHT
Dublin, Ireland

Ed. *Leo Enright is Head of Radio 2 News, Dublin.*

Spreading the Word

Sir, I do public presentations on astronomy and space flight; to date, I have done 314 shows! Of those, over 100 have been dedicated to educating the public on the Space Shuttles.

In the three most recent Shuttle presentations that I have done, I was able to mention the Hermes Project (***Spaceflight*** Jan. 1986, p.37) and cited you as my information source. Whenever I am introduced before a new group I make sure that it is mentioned that I am a member of the BIS.

CLARK B. ANDREWS
Pennsylvania, USA

Independent approaches welcomed

Sir, The February issue of ***Spaceflight*** prompts me to write to congratulate you on the excellent international coverage. At a time when the US programme is under the cloud of the Shuttle disaster, it is heartening to know that the momentum into space will continue uninterrupted with the Soviet and European programmes taking the lead. We are indeed beyond the pioneering era with enough independent approaches to guarantee that no single disaster can put in doubt the overall venture.

ROGER F. MALINA
California, USA

BOOK NOTICES

Optical Instabilities

Eds. R. W. Boyd, M. G. Raymer, L. M. Narducci, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, £30.00, pp.396.

This is the latest volume in the Cambridge Studies in Modern Optics, an international series containing books on all aspects of theoretical and applied modern optics. The present compilation contains tutorial review articles and shorter research papers by authors working in the field of instabilities, chaos and nonlinear dynamics of lasers and nonlinear optical proceedings.

Chaotic behaviour is recognised as ubiquitous throughout the physical sciences and, as the result of recent progress, a theoretical understanding of the phenomenon has now become possible. Detailed studies of optical nonlinear systems have provided some of the best examples of theoretically understood chaotic behaviour.

Space Industrialization Opportunities

Ed. C. M. Jernigan and E. Pentecost, Noyes Publications, Mill Road at Grand Ave, Park Ridge, NJ 07656, USA 1985, 601pp, $54.

This book presents a broad discussion of the opportunities for space industrialisation, an area which will become of increasing interest as the US moves towards the establishment of space stations and space platforms.

A large industrial involvement undoubtedly exists. The pertinent questions is whether and how this can be paced and guided. Enterprises which require no manned intervention, such as the space communications segment, have already developed and flourished substantially. Other enterprises are developing much more slowly, either because of the costs involved or through a lack of awareness.

Parts 1-7 of the book deals with space industrialisation aspects ranging from the scientific, political, legal and economic issues to specific matters, such as various practical materials processing approaches. An objective assessment of current space ventures and an evaluation of the potential of future projects is also included.

An appendix describes a number of specific microgravity science applications under current study, embracing such areas as electronic materials; solidification of metals; alloys and composities; fluid dynamics and transports; biotechnology; glasses and ceramics; and combustion.

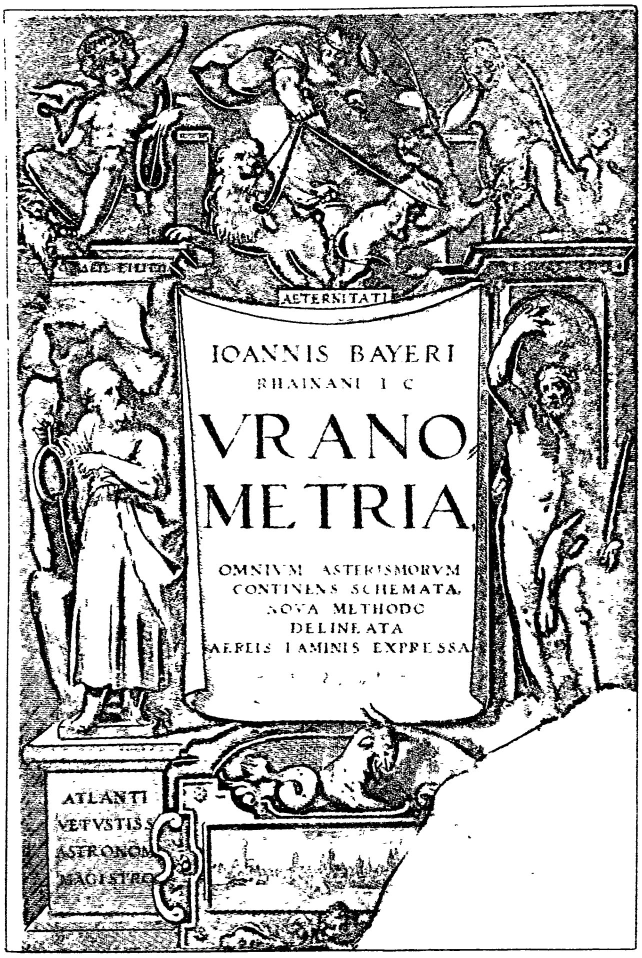
A PIECE OF ASTRONOMICAL HISTORY

As interesting articles in Spaceflight **(March and June 1985) have related, the Society is fortunate to possess a unique copy of an early important astronomical star atlas and, in view of its importance, plans to issue facsimile copies in limited edition.**

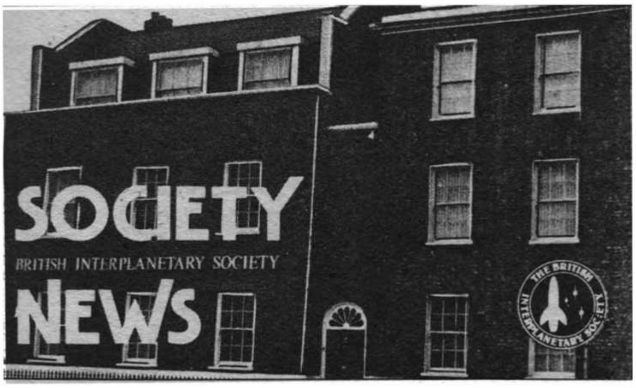
The Uranometria **(Atlas of the Heavens) first appeared in the year 1603. Its author was a Bavarian lawyer, Johannes Bayer (1572-1605). It was such a boon to astronomers that it continued as a major work of reference throughout the 17th and 18th centuries.**

Basically, it consisted of a finely-engraved frontispiece with 51 copper-engraved star maps recording the approximate positions and magnitudes of some 500 stars observed by Bayer himself, in addition to those that had formed the renowned catalogue of the Danish astronomer, Tycho Brahe, only a year or two earlier.

The Society's copy is even more important than this. The Bayer star maps are interspersed with sheets of carefully-catalogued handwritten observations identifying the exact position of each star shown for Epoch 1747. It is apparent that this is the work of a dedicated astronomer of high calibre. Research is still continuing to identify who this mysterious observer might be but early candidates have included James Bradley (Third Astronomer Royal) and George Parker (Earl of Macclesfield).



The title page of the Society's *Uranometria.*



SPECIAL TRAVEL OFFER

IAF CONGRESS, INNSBRUCK, 5-11 OCTOBER 1986

Readers intending to be present at this year's IAF Congress may like to receive details of the special travel arrangements which the Society has made with American Express.

A travel package is offered with Economy Class return air travel London-Innsbruck by scheduled airline services and hotel accommodation with continental breakfast. The party will be met and assistance provided at the airport both on arrival and departure.

Prices are in the range £250-350 inclusive of all service charges and taxes according to class of hotel selected, whether single occupancy or sharing and whether the stay is for 6 or 7 nights.

Full details of prices and booking procedure are available on request from: The Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

WE NEED A HIGHER MEMBERSHIP

More than half our new members come from personal recommendations by existing members, often as a result of a simple mention of the Society and its work or publications. We urgently need an increased membership to develop and extend our activities. Every member can participate in spreading the word about the Society. To help matters along:

(i) A simple Application Form for Membership is provided in this issue (which may be photocopied).

(ii) The Society will immediately follow up any introduction with further details and application procedure.

SPACEFLIGHT BY AIR MAIL

The Society now offers an Air Mail delivery of ***Spaceflight*** to overseas readers in non-European countries. This service is possible following the introduction of new label addressing equipment at the Society's Offices. The advantage is considerable for readers in the US, Canada, the Far East and Australia who experience delivery times of four to six weeks by surface mail.

Requests for Air Mail delivery need to reach the Society by the 14th of the month to be effective for the next month's issue and should enclose a remittance of US$2.50 (£1.50 sterling) per issue for each remaining 1986 issue.

UNWANTED BACK NUMBERS

Readers wishing to dispose of earlier issues of ***Spaceflight*** are invited to return them to the Society's offices for topping up our store of back numbers. Complete volumes are useful to have, but discontinuous numbers are equally welcome.

SURPLUS LIBRARY BOOKS

An up-dated list of surplus library books available to members at reduced prices is available on request, enclosing a foolscap reply-paid envelope.

THE BORDERS OF SPACE

Over the last three years the Society has organised a number of outstanding film shows which have, altogether, featured between 60 and 70 space and space-related topics. One effect of these has been gradually to reduce our stock of new films, a matter hastened by the advent of video.

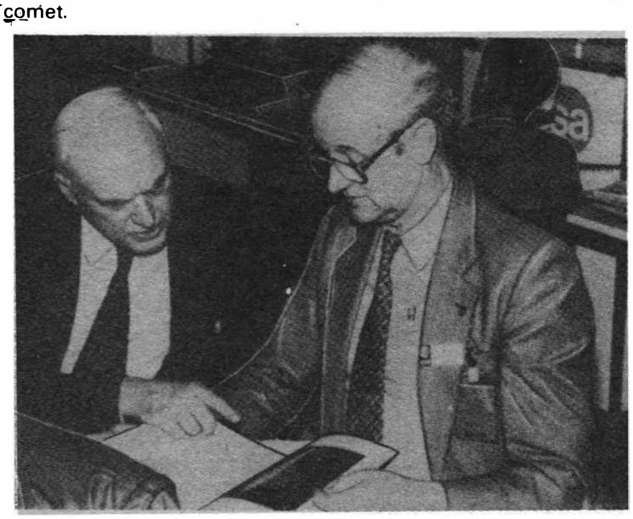
Early this year we reached the tail-end of the films available, choosing a final selection of relatively ancient vintage depicting various outstanding stages in the exploration of near-space. These were featured in two films shown on January 29 and February 26.

Imagine our astonishment to discover that both programmes were screened before capacity audiences and that many other members expressed disappointment at being unable to attend.

Those who did secure places invariably expressed interest and enthusiasm for the programme. The January programme featured an overview of Gemini, Apollo 15, Skylab and two early Shuttle flights, while the February programme provided an overview of Mercury, Gemini 4, the Apollo-Soyuz Mission, two more recent Shuttle flights and a look towards the Space Station.

In view of the interest aroused we are arranging for both programmes to be repeated next session. Details will appear in ***Spaceflight*** shortly so that those disappointed last time will be offered another opportunity.

An encounter at the European Space Operations Centre at Darmstadt in March. Norman Longdon, Head of ESA Publications, and Len Carter, BIS Executive Secretary, examine the first of two new ESA Special Reports devoted wholly to observations of Halley's comet.



FROM THE SECRETARY'S DESK . . .

Bright and Shining

An interesting book on supernovae reminded me that our library now has on display a most interesting and very rare gold coin which bears the name of the Byzantine Emperor Constantine.

Its type and style denotes it to be one issued by Constantine IX, who reigned in Constantinople from 1042 to 1055 AD. We also know this to be the last coin issued in his reign so we can date it almost exactly to between 1054 and 1055.

The figure of the Emperor, holding globe and sword, is usual and common in the Byzantine series but what is absolutely new is that this one shows an eight pointed star on each side of his head. Similar ancient coins (e.g. those of Julius Ceaser and Octavian) show that such a star indicated a major celestial event. No bright comets appeared in the skies in 1054 but what did appear was a giant cosmic explosion, a great supernovae which produced a strange object discovered only in the 18th Century and which we now call the Crab Nebula. At its heart, we now know, lies a faint neutron star, spinning on its axis at the rate of 30 revolutions per second and the subject of many a learned text in its own right.

It is exciting that our Society possesses a contemporary artefact recording this celestial wonder, issued within a year or so of the actual event.

Nuremberg Chronicle

Members may like to know that the illustration of the comet of 804 AD from the "Nuremberg Chronicle" (***Spaceflight,*** December 1985) and which was an almost-identical reproduction of the drawing intended to represent Halley's comet in the year 68 AD, was borrowed by Yorkshire TV for use in their programme "The Halley's Comet Show" televised last November.

Artistic Merit

Those who have attended Society symposia and used the lunch break to take the air and refresh themselves at the rear of our building may have wondered about the presence of an electricity Sub Station there.

The reason stems from the bankruptcy of the former owner, a property developer who, in an effort to raise funds, granted a Lease to the London Electricity Board to allow them to erect a sub-station at a pittance of £10 each year. Since then, the Society has been much engrossed in trying to get the station removed, as we badly need the room.

Now the LEB have gone, though their station is still with us since they were under no obligation to remove it. An added complication arises because our district is now a conservation area. The result is that a squat ugly block (which resembles a war-time air-raid shelter); has been elevated to the status of a building of artistic merit to be preserved for posterity.

Subliminal

A very curious episode arose with Bayer's *Uranometria* recently.

With the Printers raring to go with production of the facsimile edition and with the brochure almost complete, the only matter remaining was a review of the final text. At that point the book was re-examined once more to try to discover the date, this time armed with the information that there should be a printer's colophon giving this information. There was no such thing, but the title page and its reverse were re-examined just the same, to make sure.

I returned to assure everyone that no colophon existed but, somewhat surprisingly, the word "Polaris" was running through my mind. Puzzled, I looked again but the word wasn't on the page. Where had it come from? I retraced my steps, taking the volume back to the Conference Room where I had first opened it. There I saw, very faintly, the word "Polaris" once more. Shining a torch through the pages showed conclusively that we had discovered yet another page, stuck on the reverse of an existing page and with both then stuck together on the back of the title page!

The mystery page, thus glued and sandwiched between two others, seems to contain yet more early observations, but does it contain the exciting authentication that the volume was once owned by James Bradley?.

We must wait and see. The offending pages are now with the book restorers to see if they can be separated.

Swings, But No Roundabouts

Preparing subscription notices always underlines the need for documentation to be examined most carefully. The scope for misunderstanding is so wide that it is fatal to be less than extremely careful. I used to hope that one misconception might cancel out another but there is no Law of Averages, only a Law of Perversity which promises that anything that *can* be misread *will* be.

One example was the special 1984 introductory offer of £16, to cover both an annual subscription to ***Spaceflight*** and a free copy of *The Eagle Has Wings,* thus giving a real discount of £12. The text was so misread that one applicant claimed an allowance of £12 against the £16, and sent only £4 for everything. I even fell into the trap myself on one occasion with a NASA Memorandum entitled 'Unreliable, fault-tolerant Control Systems.' Fortunately, the title was really *Ultrareliable.*

The effort needed to avoid misunderstanding calls for an artistic bent.

History As It Was

All manner of asides stemmed from the Society's last history symposium. One that particularly took my fancy was recounted by Brian Oliver now at BAe, describing his time with Vickers Armstrong at Weybridge. It seems that, as late as the 1950's, his practice was to take company packages to Gatwick Airport and hand them over personally to the Captain of the aircraft, as often as not when about to take off! He nearly left it too late once, and had to wave the plane to a stop while it was taxiing along the runway. Nowadays, one can't even get a bus to stop.

Logomotives

I am always intrigued by logos and often wonder how each of them come to be selected. For example, the International Academy of Astronautics uses a logo depicting the stars of Ursa Major. How did it come to choose it?

More interesting examples can be identified among coats-of-arms. The shield of Harrow School carries a silver lion, which is a pun on the name of its founder, John Lyon. Coats-of-arms of schools and colleges often give a clue to their founders. Rugby School refers to its founder, who was a warden of the Grocers' Company, by a branch of dates in its crest!

The coats-of-arms of cities and boroughs tend to go back to their early days recording historic events or personages. For example, pigeons are found on the Cheltenham coat-of-arms referring to the legend of the discovery of Cheltenham's mineral waters as a result of pigeons flocking round a spring.

The BIS logo showing a stylised rocket with fins and three stars (symbolising our interest in Earth-space, near-space and deep-space) was adopted on August 28, 1954 following an invitation to members to submit suitable designs.

The winning entrant, Mr. A. R. Mason, was awarded a gift of a two-year free subscription to acknowledge his work. His design may owe something to the film "Destination Moon", widely acclaimed around that time and of particular interest to us as number of our members were involved in providing technical advice.

MEETINGS DIARY

All meetings unless otherwise stated are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ.

14 May 1986, 7-9 pm — Lecture

ARTISTS IN SPACE

by David A. Hardy

Chesley Bonestell is without doubt the 'Old Master' of astronomical art. But there were artists painting the landscapes of other worlds many years earlier – some very accurately. David Hardy shows examples of these, and of the many space artists at work today, and explains how our view of the universe has changed since the turn of the century.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed evelope.

21-22 May 1986 — Symposium

SPACE STATION EXPLOITATION

A two-day Symposium on the above theme considering the scientific and industrial opportunities offered by the Space Station and free-flying platforms and the problems of management and business planning to ensure both technical and economic success.

The programme will be as follows:

Wednesday 21 May 1986

UK Involvement in the Space Station	R. Gibson
Space Station Utilization Studies in the UK	D. D. Hardy
The Value of the Space Station to Europe (provisional)	C. Toksvig
The Potential Value of Orbiting Space Facilities to Industry	Dr. G. M. Roberts
Extending the Space Station Infrastructure	C. M. Hempsell
Space Station Control Systems – An Evolutionary View	S. G. Andrews
New Uses for the Space Station	D. M. Ashford
Towards a User-Friendly Space Station	D. E. Mullinger

Thursday 22 May 1986

International Use of Space Station Facilities	S. R. Dauncey
Using the Space Environment – A Cooperative Effort by Science and Industry	Dr. F. Kleber
Advanced Propulsion System for Space Station Applications	Dr. D. G. Fearn
Payload Operations of the Columbus Platform	D. C. Ferns and M. Dillon
Columbus Data and Communications Facilities	T. Fleetwood
Uses of Microgravity in Materials Science	Dr. B. Derby
The Realities of Bioprocessing in Space	Dr. J. F. Padday
Space Station Applications – An Assessment of Opportunities in Biotechnology	Dr. M. J. Fowler
Biomedical Exploration of the Space Station	P. A. Hansson
The Space Station in Chemical and Pharmaceutical Research and Manufacturing	M. J. Leggett

7 June 1986, 10 am – 5 pm — Forum

THE SOVIET SPACE PROGRAMME

Offers of papers are invited. Members with a special interest in the Soviet space programme are invited to attend. A registration fee of £5.00 is payable. Forms are available from the Executive Secretary on request, enclosing a stamped addressed envelope.

11 June 1986, 7-9 pm — Lecture

PROSPECTS OF A MANNED MARS MISSION BY THE YEAR 2010

by J. Daniels, *University of Leicester*

After completion of the Space Station in the mid 1990's one possible goal of the US and its partners is a manned mission to Mars. This lecture will examine the why's, how's and prospects of an actual mission by 2010.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

26-28 September 1986 — Conference

SPACE '86 – PROFILES OF THE FUTURE

A weekend conference at the Brighton Centre. The programme will be as follows:

Friday 26 September
Civic Reception and Dance, incl Supper

Saturday 27 September
Opening Ceremony

Expanding Opportunities
European Opportunities in Space (Provisional)
Dr. R. Lust
UK Space Activities in a World Context
R. Gibson

On the Edge of the Universe
The Space Scene
Dr. W. I. McLaughlin
The Outer Solar System (Provisional)
Dr. R. O. Laeser
Future Exploration of the Solar System
Dr. G. E. Hunt
A Present View of the Universe
Prof F. G. Smith
Astronomy from Space
Dr. J. L. Culhane
Starlink – Electronic Corridor of the Future
Dr. G. E. Bromage

Space Platforms : A Foothold in Space
Design Drivers for the Columbus Space Programme
P. Truss
European Participation in the Development of the Space Station
Dr. D. J. Shapland
Space Tethers
Dr. I. Bekey
Evening Banquet

Sunday 28 September

Adapting to Space
Europe's Contribution to the New Science of Robotics
Dr. H. Stoewer
Microgravity: Boon or White Elephant?
Dr. G. Seibert
Space Spectacular
H. J. P. Arnold
HOTOL
Dr. R. C. Parkinson
Interstellar Studies at the Crossroads
Dr. G. L. Matloff

LIVING IN SPACE
Presentations by Astronauts followed by an Astronaut Question and Answer Session.

Details from: The Executive Secretary, British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

LIBRARY

The Society Library will be open to members from 5.30 to 7 p.m. on the following dates:

14 May 1986
11 June 1986

Whilst every effort will be made to adhere to the published programme, the Society cannot be held responsible for any changes made necessary for reasons outside its control.

MARS EXPLORATION

The possibility of manned missions to Mars in the not very distant future is reflected in this year's scientific conference arrangements.

To coincide with the 10th anniversary of the Viking Landing on Mars, the Lunar and Planetary Institute Houston, Texas and the National Air and Space Museum of the Smithsonian Institution, Washington are cosponsoring a conference on 'Mars: The Evolution of its Climate and Atmosphere' to be held at the Hirshhorn Museum on 18-19 July 1986. The object of the conference is to examine three principal topics. The first is concerned with the present seasonal cycles of dust, water and carbon dioxide in the atmosphere of Mars, how the seasonal cycles change from year to year and how their long-term variations might be modelled. The second is concerned with the climatic history of Mars and its causative agents, such as volatile gases released from the surface. The third session is on surface outgassing, oxidation and volcanism during the planet's history. These problems are very relevant to the prospective Mars Observer mission described in ***Spaceflight*** 1985, page 202 and also on page 208 of this issue. A fourth session on the 'Volcanic and Tectonic History of Mars' is planned which will then become the theme of a follow-on conference.

A long-term programme of Mars exploration including sample return missions and manned missions is to be discussed at a major conference sponsored by the Solar System Exploration Division of NASA and entitled 'The Mars Conference'. This will be held in Washington immediately following the above conference on 21-23 July 1986.

Mars exploration receives international attention at the 37th International Astronautical Congress to be held in Innsbruck on 4-11 October 1986. During the Congress a Symposium will be held on Space Exploration with one of its four sessions devoted to 'Mars Exploration – Manned and Unmanned'. This session will be dealing with strategies for possible manned missions under Chairmen J. McLucas of Alexandria, VA, USA and V. L. Barsukov, Intercosmos Council, USSR Academy of Sciences.

Milestones

March 1986

8 James C. Fletcher appointed Administrator of NASA, succeeding James M. Beggs.

9 Vega 2, second of two Soviet probes, encounters Comet Halley.

13 Soviet Cosmonauts Vladimir Solovyov and Leonid Kizim launched in Soyuz T-15 spacecraft towards first rendezvous with new Mir Space Station.

13 European Space Agency's first deep space probe, Giotto, successfully encounters Comet Halley, passing within 540 km of nucleus.

18 Ariane V17 launch called off just seconds before lift-off after computer failed to retract umbililcal arm.

21 Soviet unmanned space tanker docked with the Mir Space Station. Progress 25 carried both fuel and bulk provisions.

28 Ariane V17 successfully launched from the new ELA-2 launch pad at French Guiana, placing Brasilsat S2 and G-Star 2 communications satellites in orbit.

DO YOU REMEMBER?

K.T. WILSON

25 Years Ago...
5 May 1961. Alan Shepard becomes America's first man in space when he is launched aboard Mercury Redstone 3/*Freedom 7* on a 15 minute sub-orbital flight.

20 Years Ago...
15 May 1966. Nimbus 2 is launched from Vandenberg. This meteorological satellite returned TV and infrared global cloud cover photos until January 1969.

15 Years Ago...
19 April 1971. Salyut 1, a Soviet space station, is launched by D-1 booster from Tyuratam, followed four days later by the manned Soyuz 10 'ferry.' Although a docking with Salyut is achieved the crew do not transfer into the station.

10 Years Ago...
4 May 1976. Lageos, the Laser Geodynamic Satellite, is launched from Vandenberg by Delta. Lageos acts as an orbital passive laser reflector helping to detect small movements in the Earth's crust.

5 Years Ago...
26 April 1981. High Energy Astronomy Observatory 2, known as the Einstein observatory, is closed down after 2½ years of successful operation because of control gas depletion. HEAO-2 greatly furthered the study of X-ray astronomy.

ESA's GIOTTO ENCOUNTERS HALLEY

by Norman Longdon

Write a science fiction novel. Decide on a theme: a manmade object is to be hurled through space to rendezvous with a small chunk of matter at a relative speed of 70 kilometres a second. Make the journey eight months long, and allow an error of only two seconds at the end of it. Throw in the fact that failure to reach the rendezvous will mean a delay of 76 years before you can try again. Then add one of those instances of Murphy's law (if anything can go wrong it will), beloved of TV soap operas: say that a bulldozer in some quiet suburb of Sydney, Australia, rips out the one set of cables linking the receiving ground stations to the waiting world some hours before the rendezvous. Obviously too far fetched for science fiction. It just happened in reality.

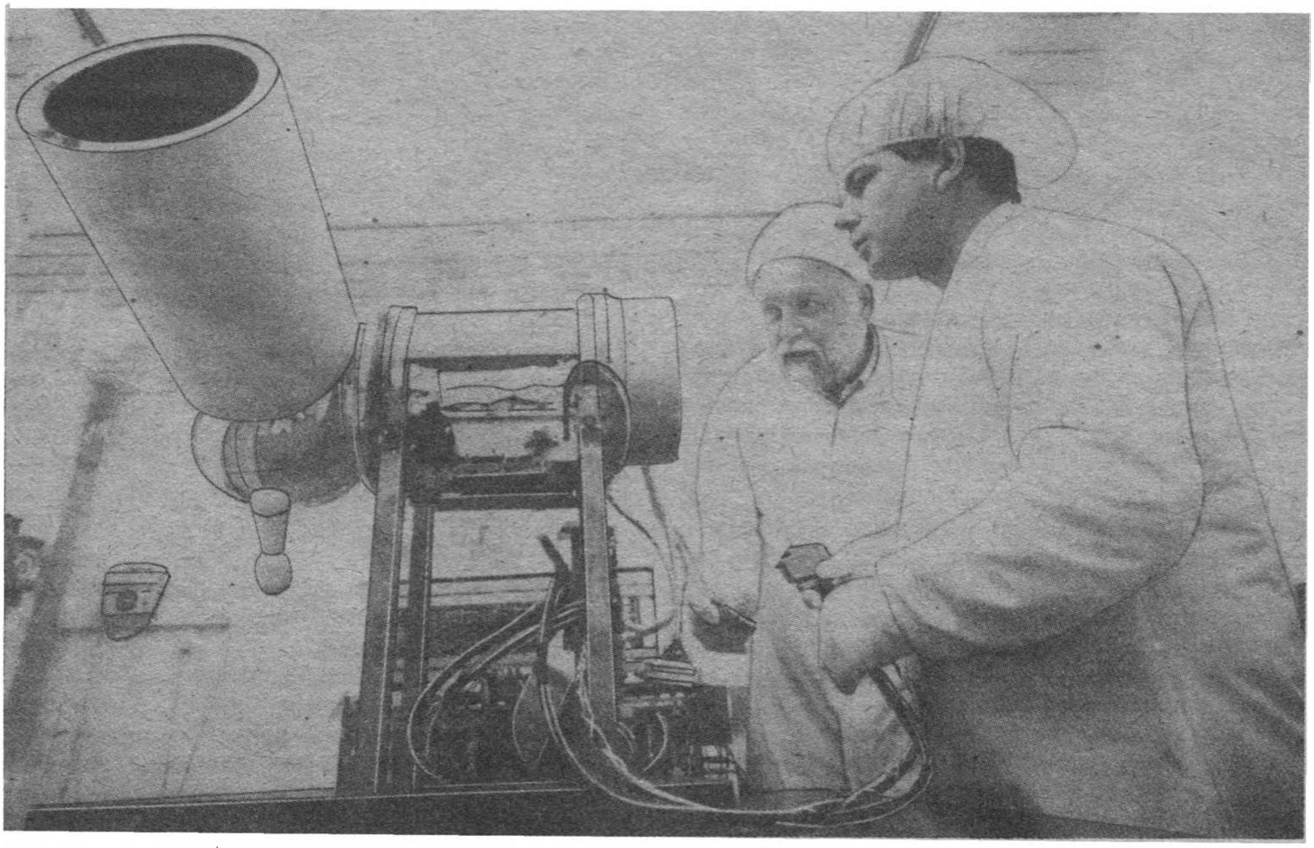
Shortly after 1 AM on 14 March, 1986, on the third floor of the European Space Operations Centre (ESOC), Darmstadt, Germany, spontaneous applause rippled from one room to the next. These were the rooms in which the scientists with experiments aboard the ESA satellite Giotto had their data receiving instruments. Here they had sat for most of the day anxiously waiting to see if years of work would bring success or failure. Had Dr. Johnson been alive he might well have added to his famous dictum 'waiting for an encounter with Halley's comet can also concentrate the mind wonderfully'. Now they could relax for a moment, for each and every experiment had worked, and the first data had told them that they had started to unravel one of the secrets of the solar system.

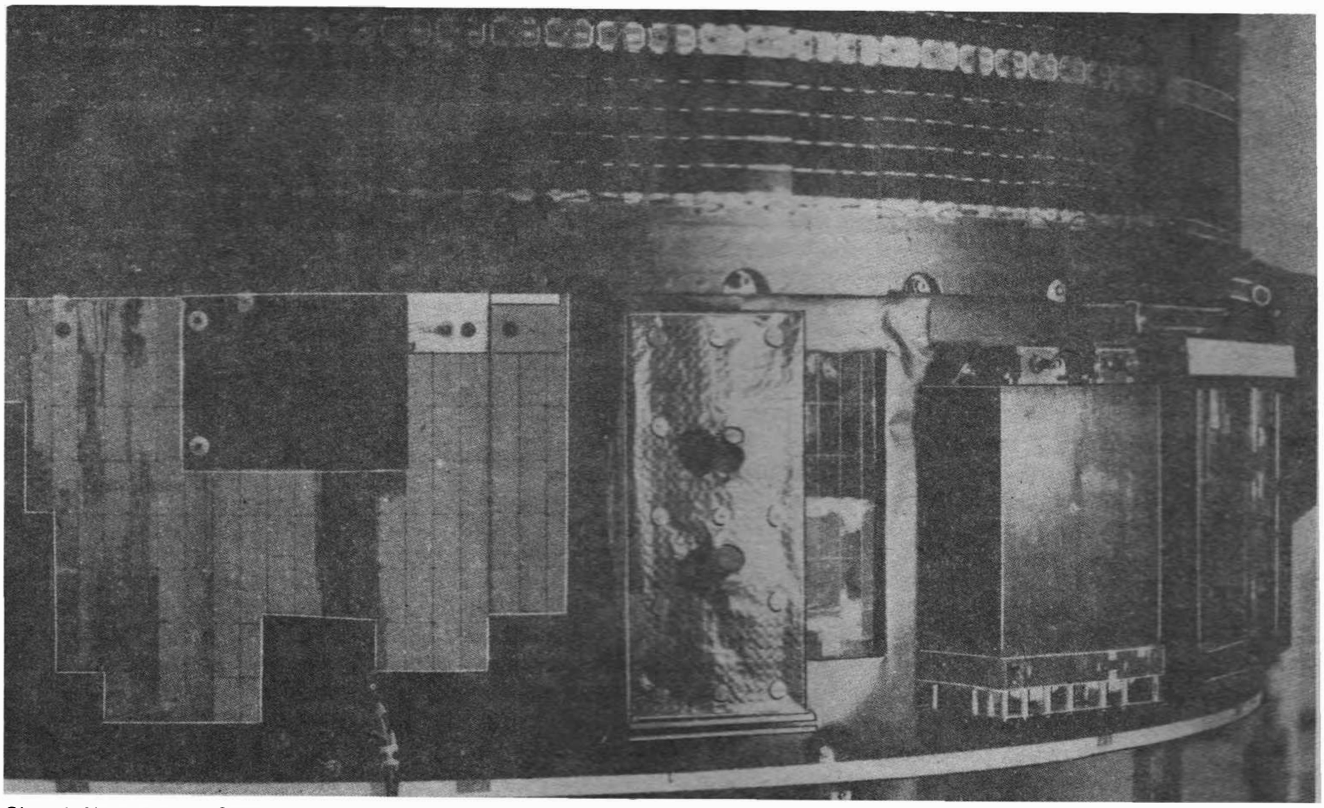
Seldom are scientists engaged in peaceful research subjected to 'instant exposure' to a public numbering millions. It was a new experience for scientists and media alike. Apart from the obvious relief and excitement which was there for all to see, the underlying theme, constantly recurring in the discussions, press conferences and interviews, was that of international cooperation. The enthusiasm for the outcome was as strongly felt by the Russian, American, and Japanese scientists present as it was by the Europeans.

From the earliest planning days, those who saw, in the latest apparition of Halley's comet, a chance to strip away one of the solar system's oldest secrets, knew that the closest international collaboration was necessary. The International Halley's Watch laboured prodigiously to coordinate the ground-based observations, and between the Space Agencies of Europe, USA, USSR, and Japan a continuous exchange of information led to the Pathfinder concept which was to ensure that the vanguard of the space fleet, ESA's Giotto, would be targetted 500 kilometres on the sunward side of the nucleus.

The Pathfinder concept called for close liaison between Intercosmos, NASA, and ESA. It was based on the timing of the Russian Vega spacecrafts' closest approach to the comet's nucleus some eight days ahead of Giotto. The Vega satellites would provide data on the position of the comet's nucleus. NASA would determine the posi-

The "eye" of the Giotto mission to Comet Halley – the Halley Multicolour Camera. It was developed at the Max-Planck Institute of Astronomy by an international team under the leadership of Dr. Horst Uwe Keller (pictured left) and Christian Becket (right).





Giotto's Neutral Mass Spectrometer.

tions of the two Vega spacecraft very accurately using the Deep Space Network (DSN), and Very-Long-Baseline Interferometry (VLBI) techniques.

The uncertainty surrounding the precise position of the comet's nucleus may surprise those who recall that this comet's orbit has been plotted so often. There were three main reasons for the uncertainty. Irregular emissions of gas and dust from the sunward side of the nucleus have a significant influence on the comet's orbit. The ground-based observations on which orbit calculations were founded assume that the centre of light in the coma would be the nucleus, whereas it could be off-set from the nucleus. In addition, no astrometric positions could be provided for six weeks in January and February as the comet was too near the sun.

Some readers may wonder why the distance of 500 kilometres for the Giotto flyby was chosen. It was a compromise between the partially conflicting requirements for the various experiments on board. Having chosen that distance it was necessary to try to achieve it with the least possible error. VLBI techniques gave the Vega spacecraft positions within 40 kilometres, the cameras on board detected the position of the comet nucleus and sent back data on its location relative to the pointing platform on which the cameras were mounted with a high degree of accuracy. It was then possible to make final adjustments to the orbit of Giotto, and to target it to within 600 kilometres; an astonishingly accurate piece of manoeuvring.

For many viewers the television screens provided a kaleidoscopic picture of false-colour images, as the Halley Multicolour Camera fed new data every four seconds during the final approach. Then with two seconds only remaining before nearest encounter. the barrage of dust through which the satellite was flying caused the spacecraft to nutate, as had been expected, and the signals were then only intermittent until the nutation dampers had completed their task some 30 minutes later.

Obviously the data from the various experiments is being analysed, and the full results of the encounter will only be available later in the year, and of course there are correlations and comparisons to be made with results from the experiments on board the other spacecraft in the fleet.. However, first results are extremely interesting, and while details may alter some of the findings, they are exciting even when presenting an incomplete, and somewhat global picture.

The Halley Multicolour Camera gave us our first, almost real-time picture of the nucleus. The camera was developed by an international team from the Max-Planck-Institut für Aeronomie in Landau, Federal Republic of Germany, and we thank the Institute for permission to use the photographs with this article. Some considerable difficulties had had to be overcome to carry out the mssion. To see the nucleus, a mirror, which was part of the camera system had to project outside the dust shield which protected most other experiments and subsystems of the spacecraft. The mirror was therefore exposed to the dust barrage. At 70 kilometres a second, dust grains the size of one millionth of a gram could degrade the mirror, and larger particles could jeopardize the whole mission. The possibility of the nucleus being obscured by a curtain of fine dust had to be taken into account, and special filters and extensive electronic im-

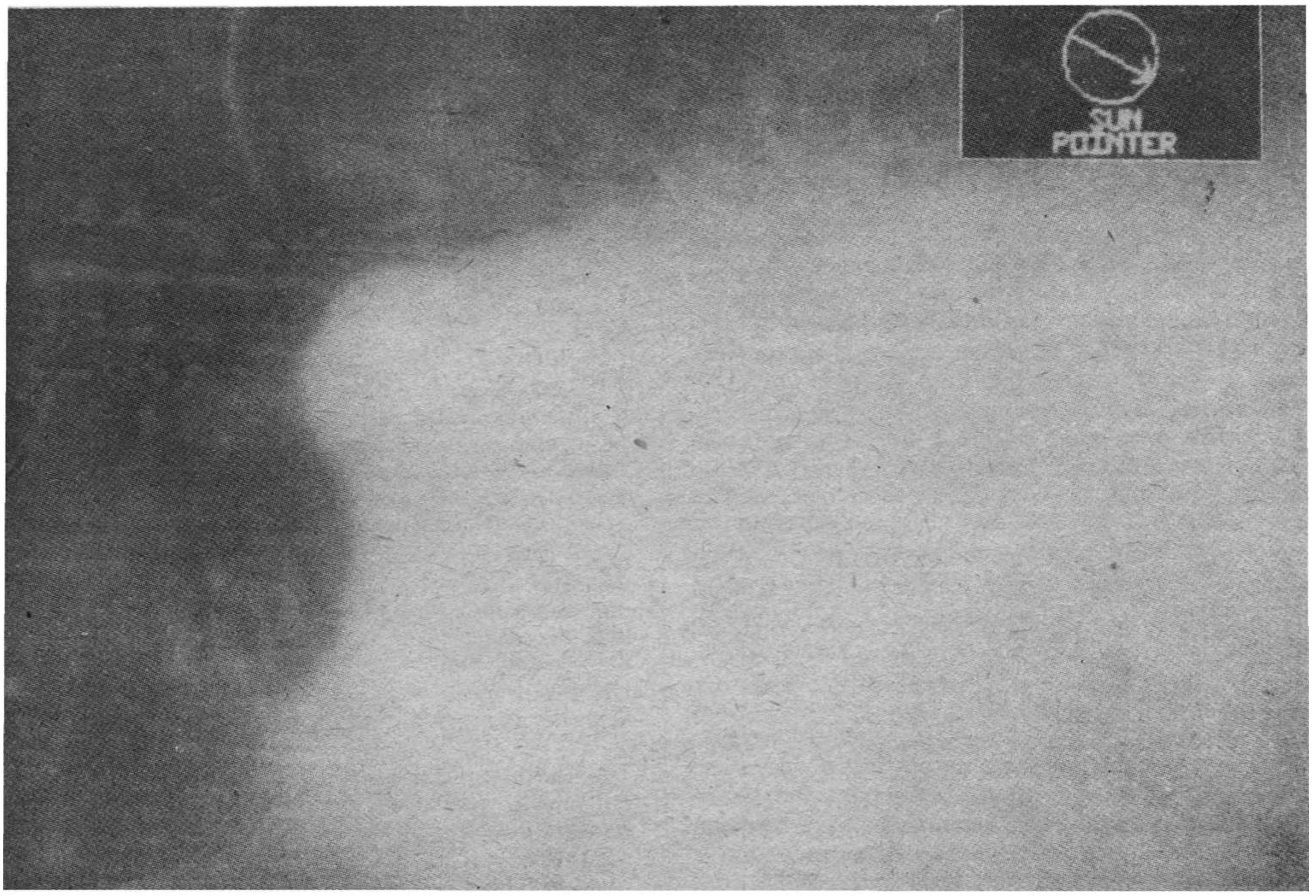
age enhancement by computer built into the system. During the approach about 2000 images were received. Coma images of Halley were obtained first 3 hours and 8 minutes before closest approach, when the comet was still 767,000 kilometres away. The nucleus was seen five minutes before closest approach when the range was 20,000 kilometres. 69 nucleus images in three simultaneous colours were received before the camera and spacecraft were hit by large dust particles. The picture accompanying this article was taken on March 14 from a distance of about 18,000 kilometres. The sun is illuminating the comet from the lower right hand corner. In the upper left hand corner there is a very dark, roughly circular area, about four kilometres in diameter. That area is part of a larger elliptical region which appears to be the solid nucleus. First estimates put the nucleus at 15 kilometres in length, and somewhere between four and eight kilometres in width. This is, of course very different from the size and shape which had bee predicted. Returning to the picture, you will see that from the right hand edge of the cigar shaped region emanate two major bright jets of dust, the lower jet being brighter and wider. These two jets extend for at least 15 kilometres towards the Sun, and represent the major apparent activity of the nucleus emanating from specific areas on the sunlit side.

The first conclusion then is that the nucleus is somewhat larger than had been expected and is irregular in shape, certainly not spherical. It seems almost certain that the surface of the nucleus is absolutely black — black velvet was how it was described. As a result it is thought that the surface is warmer than had previously been calculated. This is not in contradiction with Whipple's icy conglomerate model, but does suggest much more dust on the surface than had been expected.

The initial results from the dust particle experiments bear out the concept of jet rather than global homogeneous activity. First results from the Dust Impact Detection system (DID) indicated that everything was very quiet until one hour before nearest approach. DID consisted of six independent subsystems, with the objective of registering the impacts of all particles of significant mass incident on the probe. To determine the mass spectrum of the dust down to 10^{-17}g, the detectors were mounted on the front dust shield. An additional detector was placed on the rear shield to monitor those dust particles which penetrated the front shield. It was not until T minus two minutes that a 30 microgram particle penetrated the front dust shield. The flux rate remained low until very close to the centre. During the post-encounter press conference, the Principal Investigator described it in words : we waited much longer than expected, and then seemed to hit a wall of particles very close to nearest approach. Some of the smallest size range of particles (10^{-17} grams) had been found

This picture was taken on March 14, 1986 at 00.06 GMT from a Multicolour Camera on board the Giotto spacecraft from a distance of about 18,000 km. The Sun illuminates the comet from the lower right corner of the scene as indicated by the arrow in the inset. In the upper left corner one sees a roughly circular, very dark area having a diameter of 4 km. That area actually is part of a larger elliptical region of 15 km in the longest dimension and at least 8 km in the shortest, which appears to be a solid nucleus. It is somewhat larger than expected.

From the right edge of that cigar-shaped region emanate two major bright jets of dust, the lower jet being brighter and wider. These two jets extend for at least 15 km toward the Sun and represent the major apparent activity of the nucleus emanating from specific areas on the sunlit side.



previously in deep space but had not been associated with cometry physics. It seems that a new regime of particles has therefore been discovered.

Early results from the Giotto Particle Impact Analyser (PIA) which will prove information on individual dust particles and the average composition and mass distribution of cometry matter released by the comet also show that space was unexpectedly clear in the neighbourhood of the comet. The spectra so far examined show mostly carbon, nitrogen and oxygen with small quantities of derivitives. The dust fluxes were rather low with particles mainly in the 10^{-16} to 10^{-10} gram regime.

The Optical Probe Experiment had been designed to provide in-situ photopolarimetric data on both the dust cloud and the gaseous atmosphere in Halley's coma. It found an increase in gases about 150,000 kilometres before the encounter. No strong increase in the dust was recorded until 50,000 kilometres, after which there was a very rapid increase. Small inhomogenities were found in the dust, as was evidence of some jet structure. A sharp increase in CO^+ was recorded just before encounter. The colour channel of the instrument showed dust ratios indicative of dust segregation as a function of size along the Giotto trajectory. The team responsible for the OPE hope that they can link the Giotto data and ground based data.

The Radio-Science experiment found that the density profile against the distance from the nucleus had a steeper decay gradient than had been expected.

The initial picture then is of main emissions being from jet sources rather than a homogeneous pattern, and a wall of dust near to the nucleus, with a much more diffuse nature to the coma outside the immediate vicinity of the nucleus than had been expected.

The Magnetometer, with a primary role to investigate the interaction between the comet and the solar wind at a distance of 0.9AU from the Sun, to within 500 kilometres of the nucleus, and a secondary intention to study the interplanetary magnetic field, functioned very well both inbound towards the nucleus, and afterwards on the outward bound journey. Only during the period of nutation was there a loss of signal. Upstream waves were found at 7 million kilometres, and the bow wave was seen at 1,150,000 kilometres at 1930 hours on 13th March. The maximum magnetic field was recorded 16,000 kilometers from the closest encounter, and the Ionopause at 5000 kilometers.

The Three Dimensional Positive Ion Analyser detected particle energies from 10eV to 10^4eV. The outer edge of the hydrogen coma was recorded at 7.8million kilometres, then there were increasing numbers of ions, with waves of greater amplitude and frequency Evidence was found of turbulent flows in the transition region associated with the bow wave., after which recordings were smoother, through to the closest approach. Data was collected until one hour after encounter. Cometry ions of the water group were clearly seen. It seems evident that there is an interaction between the solar wind and the comet more than 7 million kilometres from the nucleus, and that there is considerable activity outside the bow wave.

These findings were confirmed by the RPA- Copernic Plasma experiment which measured the three dimensional distributions of electrons between 10eV and 30keV, and the composition and distribution close to the comet of thermal positive ions. This experiment also recorded a sharp temperature increase just before the encounter.One of the sensors of this experiment found near the comet, ions in O^+, OH^+, H_2^+. CO^+.CN^- and N_2^-, HN^2, and S and S_2^+ and iron, cobalt, copper nickel, and also some ions having a mass greater than 100 atomic mass units.

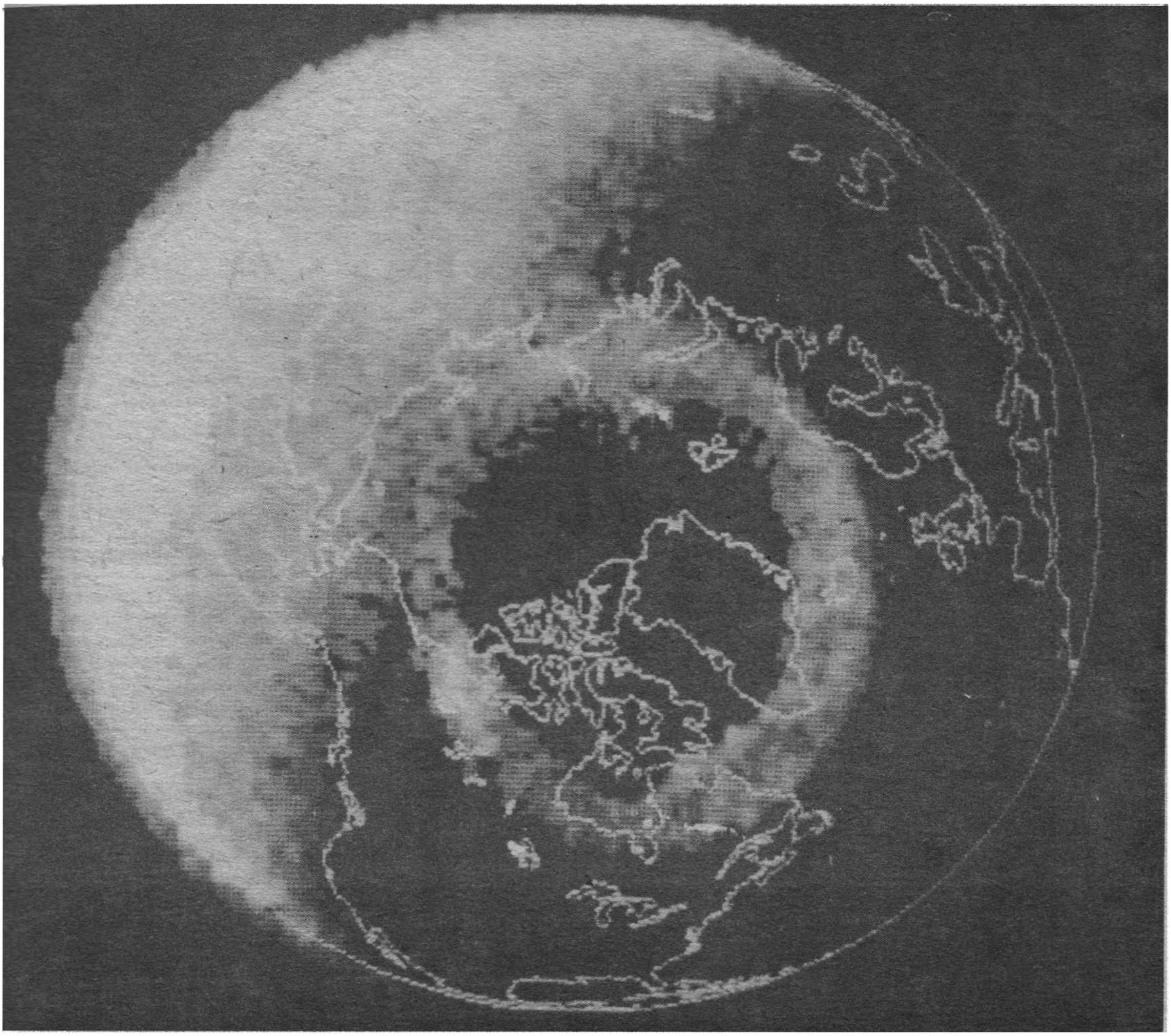
The Ion Mass Spectrometer consisted of two sensors: one optimised for the outer, and the other for the inner coma, both featuring mass imaging characteristics, permitted simultaneous measurements of several ion species by means of multi-detector arrays. The sensors recorded that the bow wave deflected the solar wind by 15° and alpha particles heated up as the bow shock was manifested. As the spacecraft came closer to the nucleus, further discontinuities were noted with warm cometry ions (mainly carbon and water) recorded in the medium and high mass ranges. As the spacecraft approached the nucleus, the ions found were colder, and one minute before closest encounter very cold ions were recorded. In general the findings were that the amounts of metal ions were low, and there was little sodium.

The energetic particle experiment studied ions and electrons at greater than 20keV and recorded at 1.4 million kilometres an initial rise to 6×10^4 particles cm^{-1} sec^{-1} $ster^{-1}$. Thereafter intensities decreased slightly, and at closest approach there were exciting complicated events which will require further analysis.

Finally, the Neutral Mass Spectrometer found water vapour, H_30^+, and H_20^+, and other ions. At the time it was very difficult to interpret what other gases were present, but it was reported that more ions had been seen than had been expected, with slight indications of iron and sodium. Initial calculations suggest water vapour production to be approximately 2×10^{30} molecules/sec, assuming gas streams from the nucleus of 500 metres/second (60 tons/sec .

Clearly there is much further research for the scientists to mull over before the full stgory is told. But the story of the encounbter would not be complete without recording that two great names in cometry circles were there to witness the event. Professor Oort, whose theory of the origin of the comets could be confirmed or amended by the results, recalled how the 1910 apparition had stimulated his interest in comets, and celestial mechanics. Here was an octogenarian who still had a lively interest in his subject. And with him was Professor Fred Whipple whose 'dirty snowball' theory was being put to the proof. This kindly and courteous man was as excited as the youngest scientist as the evidence came in.

The European Space Agency had shown that with colleagues in the USA, USSR, and Japan, there could be genuine joint ventures in pursuit of the common goal of learning more about the universe, and Man's place in it.



AURORAL OVAL FROM SPACE

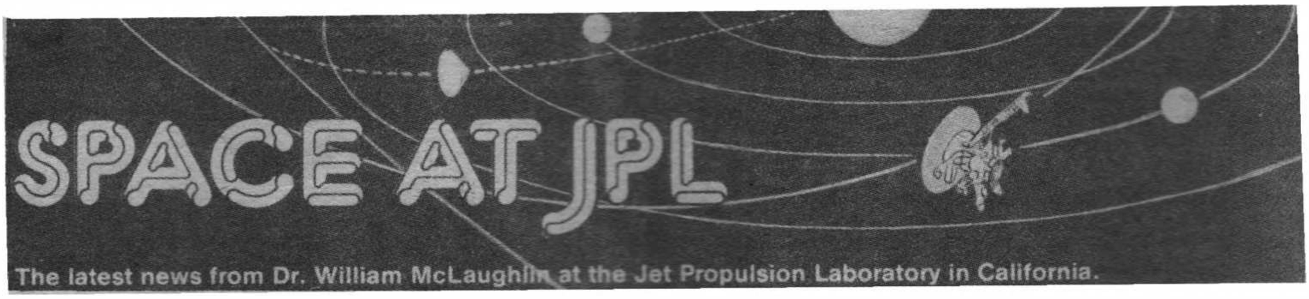
The intriguing displays of light of the aurora borealis are a familiar sight at high northern latitudes. Guided by the Earth's magnetic field, they arise in a circle or oval surrounding the Earth's magnetic north pole (which is located in the north of Greenland) at magnetic latitudes close to 68 degrees.

This stunning photograph was provided by the Dynamics Explorer-1 spin-scan auroral imager of the University of Iowa which monitors the global location of the auroral oval. At this particular time, auroral activity was at a modest level and the oval extends no further south than northern Scandanavia in Europe. At times of high activity, the oval enlarges and the lights are visible in other parts of Europe and the USA. Daylight is to the left of the photograph.

Dynamics Explorer-1 (DE-1) was one of a pair of satellites launched on 3 August 1981 into polar orbits from the Vandenberg AFB, California. DE-1 was placed in a highly elliptic orbit (apogee 23, 295 km, perigee 559 km) while its companion satellite (DE-2) was placed in a lower orbit (apogee 996 km, perigee 298 km).

The primary purpose of the programme was to make a detailed study of the transfer of energy from the hot, tenuous plasmas of the Earth's magnetosphere into the colder, denser gases of the upper atmosphere. These processes are responsible for the creation of the aurora. DE-1 carried six different experimental equipments including the Spin-Scan Auroral Imager, which besides providing the first global imaging of the aurora, also mapped ozone concentrations and discovered meteor 'holes'.

Acknowledgement: ***Dave Dooling,***
Essex Corporation



Satellite Discovery Bonus For Navigation Optics

Navigation of interplanetary spacecraft to Venus and Mars in the 1960s was based upon information obtained through radiometric data. However, during the Mariner 7 mission to Mars in 1969 an unofficial optical navigation demonstration was conducted using the television camera onboard the spacecraft.

The great advantages of onboard optical navigation are that it results in measurements relative to the objects of interest, rather than relative to the Earth, and it becomes more accurate as those objects are approached. Generally, radiometric data types (doppler, ranging, interferometric) decrease in accuracy as the distance from Earth increases. An exception occurs when a spacecraft is close enough to feel the tug of its gravity, thus influencing the frequency of the radio signal (doppler effect). For example, the orbit-determination process for the Voyager 2 encounter with Uranus began to benefit materially in early January of 1986 when the spacecraft fell sensibly under the influence of the Uranian gravity; closest approach to the planet took place on January 24.

The Mariner 9 mission, which was launched and achieved orbit about Mars in 1971, included a formal Optical Navigation Demonstration. It was based upon imaging the Martian satellites Phobos and Deimos against the star background which, in turn, permitted inference of the location of the centre of mass of Mars. The demonstration was successful and actually supplied some comfort to the project by confirming the spacecraft state near the time of insertion into orbit about the planet.

This computer-assembled mosaic of the Uranian moon Miranda includes many of the high-resolution frames obtained by Voyager 2 during its flyby in January 1986.

The Viking mission to Mars, featuring two Orbiters and two Landers which arrived at the Red Planet in 1976, was designed to be successful with the use of radiometric data alone. But optical navigation was included, in a role expanded beyond that of Mariner 9, in order to enhance Viking navigational capabilities and to gain experience for missions to the outer planets. Mars, Phobos, and Deimos were imaged using stellar reference systems, and the optical orbit determination effort was successful. For example, the limb-measurement technique was very precise, enabling the centre of Mars to be located within about one per cent of its radius, i.e., about 35 km.

With this solid base of experience in place, the stage was set for the use of optical navigation on the Voyager mission to the outer planets. Voyagers 1 and 2 were launched in 1977 and were the first spacecraft to employ optical measurements as a required data type. Without the combination of radiometric and optical data the Voyager flybys of Jupiter, Saturn and Uranus (with Neptune scheduled for 1989) would have yielded much less scientific return.

Much of the direction of the ongoing optical navigation effort at the Laboratory has come from Dr. Stephen Synnott, who supervises JPL's Optical Systems Analysis group. Synnott came to JPL in 1975 from the Massachusetts Institute of Technology and began planning optical navigation for Voyager. Each of the five outer-planet encounters (two Jupiter, two Saturn, and one Uranus) in which he has participated has been characterised by its own particular set of challenges.

Unlike the Martian satellites Phobos and Deimos, the four large Galilean satellites of Jupiter were not star-like in appearance, so centre-finding techniques had to be invoked, as with the planet Mars. The satellite centres were geometrically inferred from observations of their limbs, and the limb locations were referenced to the stellar background. Thus, in effect, the centres of the satellites were located against the stellar background, enabling the parameters of both the satellite and spacecraft orbits to be improved.

A problem was posed to Synnott and his team at the Voyager 1 encounter with Jupiter when the Imaging Team wanted to observe from close range the small satellite Amalthea, whose orbit was poorly known. The satellite itself was darkly hued, making it difficult to observe in distant views to determine better its orbit for the desired close-range imaging. Consequently, Synnott sought images of Amalthea in transit across the disk of bright Jupiter. The problem was made more difficult by the availability of only small arcs of the limb of Jupiter in these transit images (from which the centre of Jupiter had to be inferred) and further compounded by the inherently fuzzy nature of the limb of the gas giant. Unlike most satellites and the terrestrial-type planets, the photometric functions of the disks of the gas giants – Jupiter, Saturn, Uranus, and Neptune – are not well behaved, i.e., the limb of

the planet is not crisply defined. Nevertheless, the measurements were made, the orbit was refined, and the desired scientific observations of Amalthea resulted.

After the experience gained with Voyager 1, Synnott characterised the Voyager 2 encounter with Jupiter as "much smoother".

For the two Saturn encounters the six larger inner satellites – Mimas, Enceladus, Tethys, Dione, Rhea, and Titan – were used for the purpose of optical navigation of the spacecraft. However, by the time of the second Voyager encounter with Saturn, a total of 17 satellites – some discovered from the ground, some by spacecraft – were objects of scientific interest for the Imaging Team.

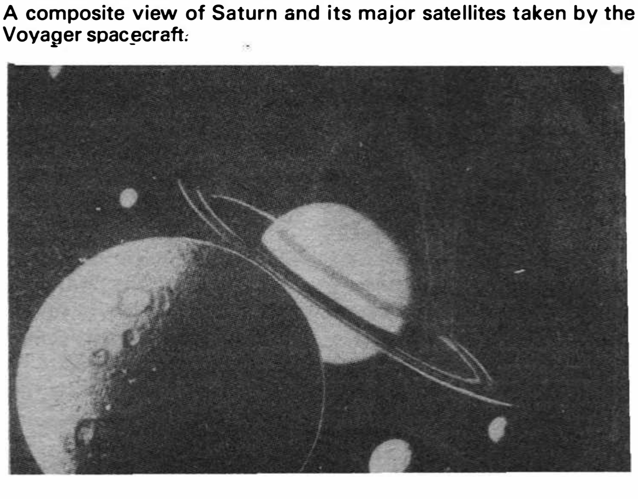
Motion of material in the F-ring of Saturn also became a topic for orbit determination by optical means. Clumps of material were identified and tracked, allowing a precise computation of their orbital motions just as if they were conventional satellites. Then, when the spacecraft approached more closely to the F-ring, it could be appropriately rotated to null out the apparent motion of the ring material, thereby allowing smear-free images of the ring to be obtained. This technique is called image motion compensation (IMC) and played an important role at Uranus.

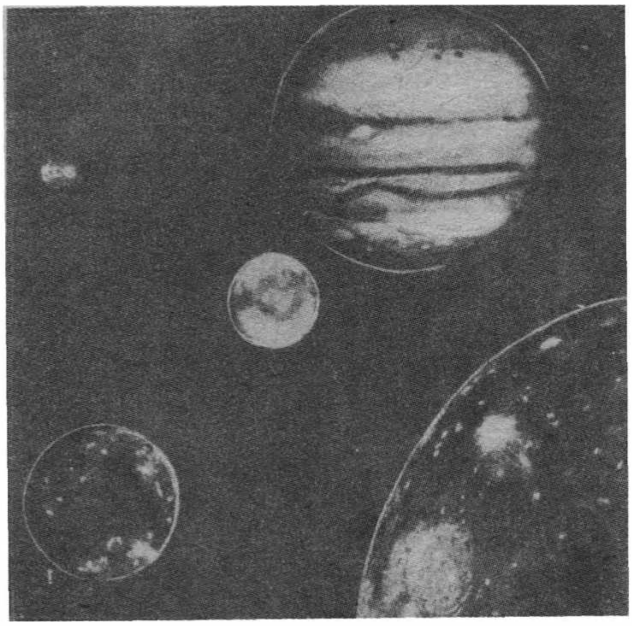
The total navigational task at Uranus, radiometrically and optically based, was extraordinarily precise (see the March issue for some of the details) with the position of the spacecraft known to within about 30 km at the time of the encounter. This accuracy facilitated the IMC and pointing for the exceptionally clear images of the satellite Miranda which Voyager 2 returned. That bizarre geological hybrid was flown by at a range of 29,000 km, and resolution of features as small as 600 metres was obtained. Dr. Bradford Smith, Principal Investigator of the Imaging Team on Voyager, characterised the Miranda images as the best ever obtained from a flyby mission.

In addition to performing optical navigation functions, Synnott has discovered a total of nine satellites: two at Jupiter and seven at Uranus. He has assembled evidence for several suspected new satellites at Saturn, but not enough confirmatory imaging frames were available to allow definitive orbits to be announced. The satellite search experience at Saturn was one of the reasons that the Voyager project planned its imaging strategy differently at Uranus; the success of this planning was demonstrated by the seven new satellites discovered by Synnott plus three additional satellite discoveries from other sources.

He became involved in satellite hunting as a result of a previous Jovian satellite discovery made by D. Jewitt. Synnott determined the orbit of this satellite, later called Adrastea, from the discovery frames which spanned only about one per cent of an orbital period. He was curious to see if his Adrastea orbit could be reliably extrapolated. Searching for about one year after the encounter in the Voyager file of images, he found two small, circular shadows against the disk of Jupiter. At first he thought that these were evidence of Adrastea, but computation showed that it must be a new, previously undiscovered satellite. This, Synnott's first discovery, has been named Thebe. During the act of producing a reliable orbit for Thebe, he come upon other satellite sightings which did not fit the orbit; they became evidence for his second discovery, the satellite Metis (see *Icarus 58,* 178-181 (1984) for his technical description of the Jovian satellite hunt).

A composite view of Saturn and its major satellites taken by the Voyager spacecraft.





Jupiter and its four planet-size moons, the Galilean satellites, were photographed in March 1979 by Voyager 1 and assembled into this composite picture.

Synnott's satellite discoveries at Uranus were facilitated not only by picture planning but also by new computer tools which were largely designed, built, and tested by two of his optical navigation colleagues, Ed Riedel and Juli Stuve. By this time they had produced a detailed graphical catalogue of the numerous faint blemishes on the vidicon of Voyager 2's camera. This colour-coded catalogue could be superimposed on images displayed on a TV screen in the navigational area. Thus, much time-consuming confusion with potential new satellites was eliminated. One is reminded of Messier's famous catalogue of nebular objects which he produced in order to speed up his search for new comets (but while Messier had just over 100 objects in his catalogue, optical navigation lists several times that many known blemishes in its catalogue). Another very useful feature is the capability to designate a suspected satellite on the screen with a cursor and instruct the computer to draw a small box on a subsequent image where that satellite would be expected to appear. If the box is empty, the candidate has failed the test. If there is an object in the box and it is not a blemish or catalogued star, a new satellite may have been discovered.

Voyager 2 is now enroute to Neptune, and it is quite probable that Synnott and his colleagues will find the fishing in those waters to their liking.

GALILEO WINDOW OPENS JUNE 1987

My first knowledge of the Challenger disaster came when I was walking across the Mall at JPL. Joel Davis, a journalist who is writing a book on the Voyager encounter with Uranus, came running up to me and said that the Challenger had just exploded. Certain sudden events are mind numbing – their enormity cannot be grasped at once – and the mind takes side trips. Mine went back to November of 1963 and visualised myself standing outside on the Berkeley campus of the University of California and being told of the assassination of President Kennedy.

In my office at JPL the two desk-top TV monitors showed strikingly different scenes. We had just passed the planet Uranus and Voyager 2 was sending back images of the crescent planet, a perspective never before seen by man. On the other monitor the TV camera at the Cape had been pointed toward the Atlantic Ocean, and the waves rolled slowly to shore in this memorial scene.

The emotional effect of the accident upon people at the Laboratory was intense. There was the natural human tie to the seven onboard the Challenger, a tie strengthened through the recognition of colleagues who were also engaged in the exploration of space.

It is still too early to gauge with any accuracy the long-term effect of the Challenger accident upon the programme of planetary exploration, which is the principal task of JPL. The immediate effect has been the postpone-ment of this month's planned launches of the Galileo mission to Jupiter and the joint ESA/NASA Ulysses solar-polar mission.

Since both missions are involved with Jupiter (Ulysses uses that planet to shape its out-of-the-ecliptic trajectory), their direct launch opportunities occur only about every 13 months when Earth and Jupiter assume proper relative positions. Thus, the next direct launch window would open in June of 1987. It is theoretically possible for Galileo to employ a gravity assist from the Earth before setting out to Jupiter. This type of action, a so-called delta-VEGA manoeuvre, has been planned for the proposed ESA/NASA Cassini mission to Saturn (see last month's "Space at JPL"). A delta-VEGA set of opportunities exists in the period September-December in 1987, but the longer flight time to Jupiter (compared with a direct launch) makes this manoeuvre a mixed blessing.

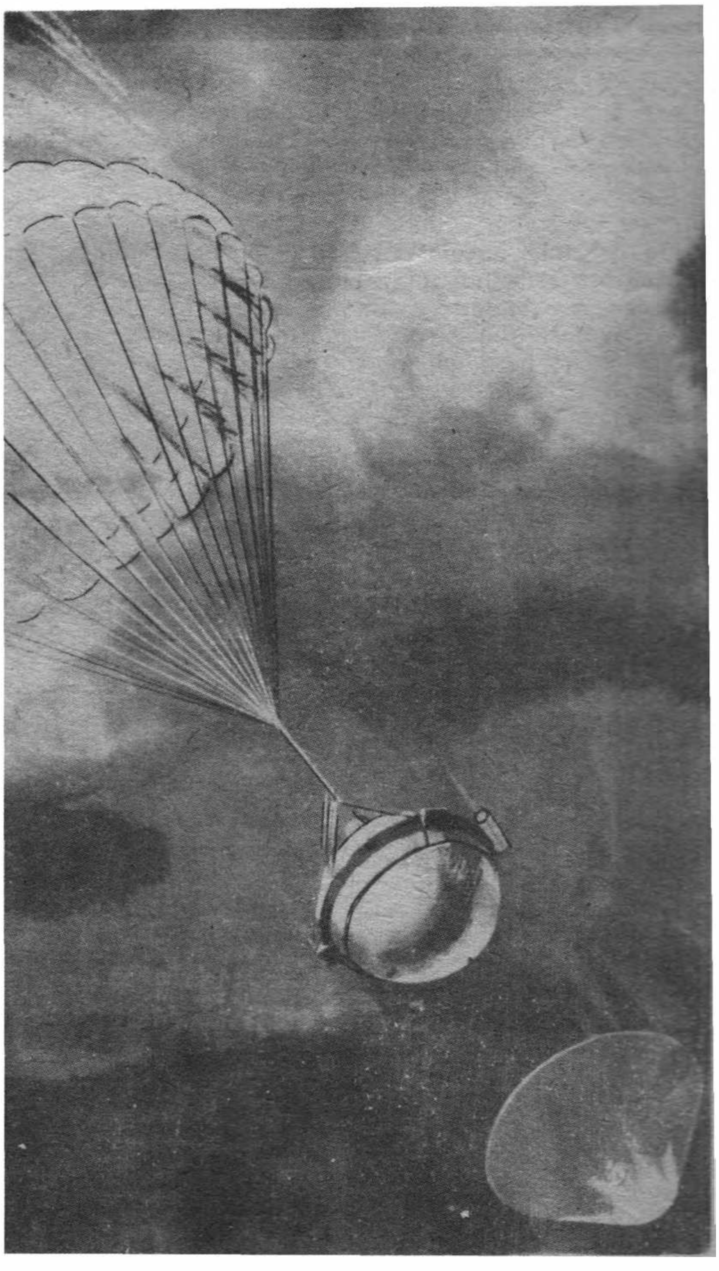
No other system exists that is immediately available to lift Galileo. Future, expendable boosters (like the Titan 34D-7) could not be available until at least 1990, and Galileo with its Centaur upper stage was specifically designed to be compatible with the Shuttle.

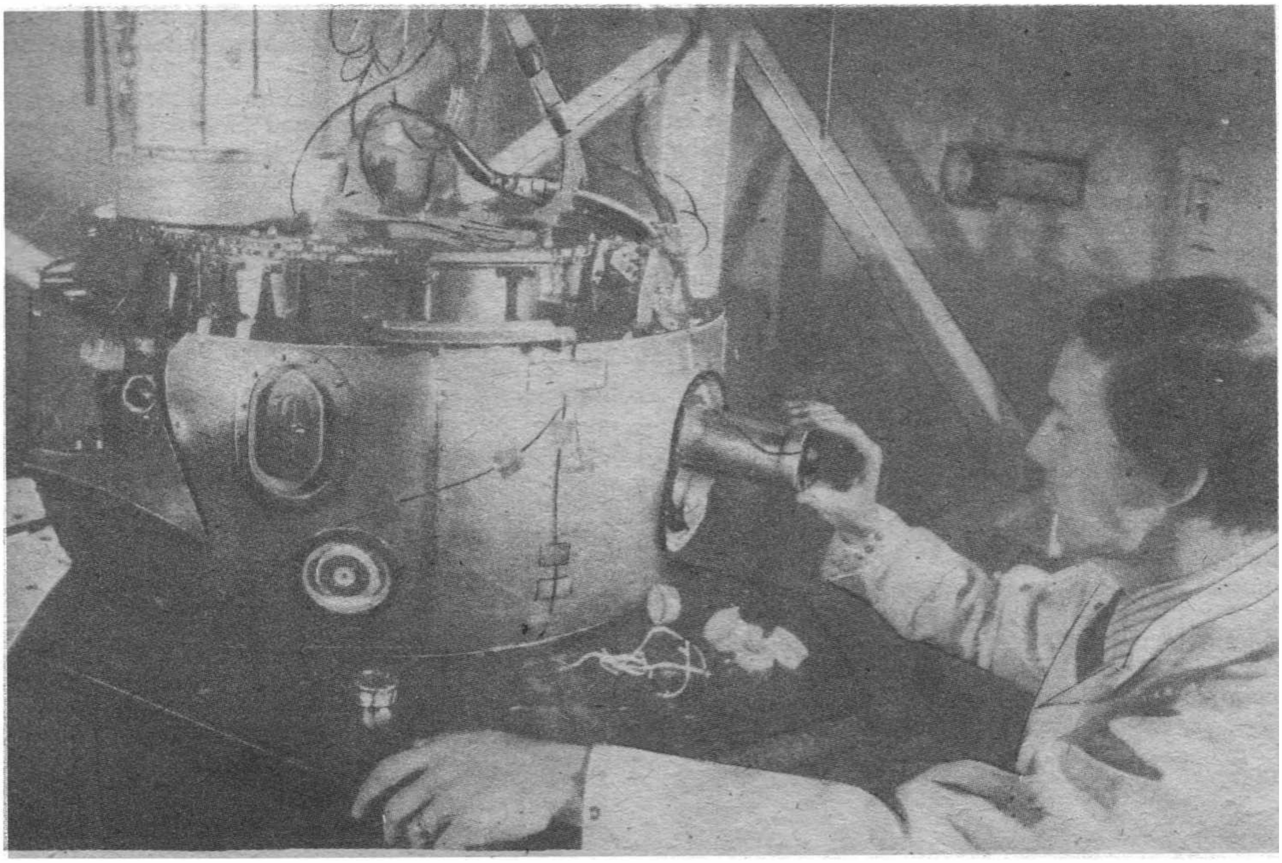
The Galileo spacecraft was shipped by truck convoy from JPL on December 19 and arrived at the Kennedy Space Center on December 22. Current plans include the continuation of spacecraft test and integration which have been ongoing since arrival, including mating the Centaur to the spacecraft. The activity may include an integrated countdown demonstration test with the Atlantis on Pad 39.

Then, the plan calls for "active storage" at the Cape. This would allow continued testing throughout the year, prior to the earliest possible launch in the summer of 1987. At the same time, JPL's mission designers will be working on revising the flight plan to fit the new possible launch date. A casualty of the launch postponement is the Amphitrite flyby option which Galileo could have performed in December 1986. It is unlikely that an asteroid as large and interesting as 200 km diameter Amphitrite will be found for other Galileo passages through the main belt.

Galileo project manager John Casani is optimistic about the future: "The Challenger accident was a tragedy of great human dimensions, touching not only the lives of those personally involved, but the entire nation as well. It will certainly affect the space programme, but it will not stop it. The problem will be resolved, and the programme will go on."

The Galileo probe will become the first man-made object to pierce Jupiter's atmosphere.





An engineer works on the Galileo probe during an early stage of preparation. Following cancellation of its planned launch this month the Galileo mission is now expected to be launched in June 1987 if the Space Shuttle is operational again by then.

WHERE ARE THEY?

There are certain questions that have appeared at precisely the right time to stimulate a seemingly disproportionate amount of discussion and investigation. Where is the source of the Nile? What killed the dinosaurs?

Bound up with the search for extraterrestrial intelligence (SETI) is the question "Where are they?" It is said to have been asked many years ago by Enrico Fermi (1901-1954), who won the 1938 Nobel prize in physics for his work on neutron bombardment. The point of the question is that if the Universe is filled with intelligent creatures, as some have postulated, why haven't they visited us?

Some thought and some calculations are required before one can determine whether or not the question is pivotal. It turns out that "Where are they?" is indeed a very good question. Since Michael Hart reintroduced the topic in 1975 with his paper in the *Quarterly Journal of the Royal Astronomical Society,* the absence of extraterrestrials on Earth has vied with search strategies as the most frequently discussed aspect of SETI. The Interstellar Studies issues of *JBIS* are replete with such papers.

The force of the question derives from the fact that even with very modest rates of interstellar migration the Galaxy would be colonised by one spacefaring race within 50 million years, a length of time which is less than one per cent of the age of that structure.

Two categories of explanation are popular for the purpose of explaining the absence of extraterrestrials. The first claims that they don't exist; humans are unique or rare in the Universe. This is the answer of Hart and his school. The finger of existential blame is pointed, variously, at the improbability of the origin of life, or its evolution or its acquisition of intelligence.

This type of explanation rubs against the Copernican grain which textures modern science. One always suspects a theory whose linchpin is some special condition achieved only by the human race, whether it is occupying the central place in an Aristotelian universe or being the only intelligent life form in a Universe of 10^{22} stars.

However, the second category of explanation does not provide much intellectual comfort. It is filled largely with holding actions or *ad hoc* theories. The former are exemplified by explanations which claim that interstellar travel is difficult or unpopular; the latter are represented by the "zoo hypothesis" of J. A. Ball (stating that we are isolated from contact in some kind of a Galactic preserve).

Perhaps another question is in order: is there a third alternative? The beginning of an answer can be stimulated by a visit to a nearby anthill. The ant is one link in the biological chain. It is a competent insect with its own view of the world. We figure little, if at all, in that world view except as occasional anonymous originators of natural disasters such as floods and earth movements. Ants are separated from us by some 200 million years of evolution, a number which is of the same order of magnitude as the 50 million years quoted earlier, and, in effect, we do not exist for the ant.

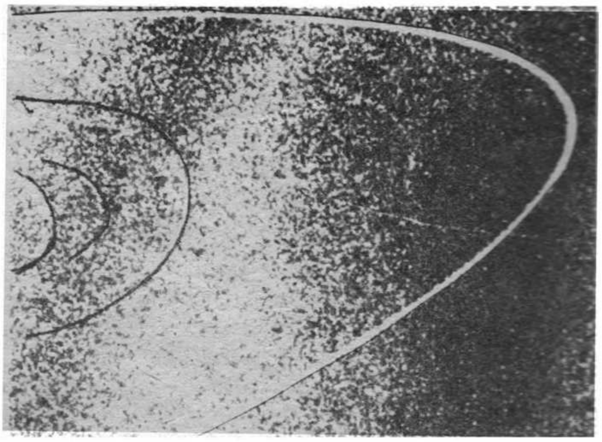
Looking at the current rate of technological and cultural evolution, which may be leading to the emergence of intelligent machines as the next step, it is not difficult to believe that perceptual "invisibility" would be achieved by an organism 100,000 years in advance of us. (Allan Wilson, writing in the October 1985 *Scientific American,* has remarked upon a correlation between the level of intelligence and the rate of evolution.) This is about the amount of time that a wave of colonisation might be expected to take to reach Earth from one of the closer, populated stellar systems even if the Galaxy were densely speckled with a million sites of origin of life (we distinguish the slower process of colonisation from more rapid exploratory probes, which would not necessarily be noticed by us).

Thus, a candidate for resolving the dilemma of "where are they?" is the epistemological solution (epistemology is the theory of knowledge): significant evolution occurs on time scales less than those of interstellar migration. Another way of looking at the hypothesis is to rephrase Fermi's question: "Where are the hominid-like extraterrestrials?" With the pronoun expanded in this manner the answer becomes: "They evolved beyond our range of recognition." A major strength of the theory is that every migrating race would be exposed for a long period of time to the adaptive pressures of new environments.

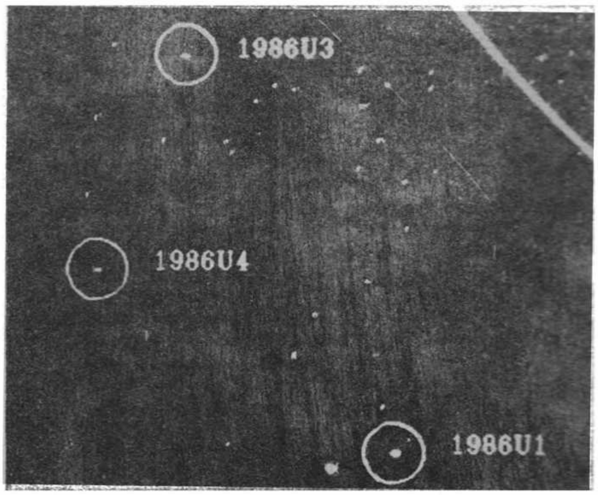
The epistemological solution may be an interesting contender, but can it be tested? One means of testing a theory is to see if it explains more than its original domain of application. Your correspondent has addressed the SETI problem along with three similar problems in a recent paper ("Kantian Epistemology as an Alternative to Heroic Astronomy", *Vistas in Astronomy 28*, pp. 611-639, 1985). In addition to exobiology the problems involve observational astronomy, cosmology and quantum mechanics.

If the epistemological solution is true, what are the implications for SETI? Current approaches to SETI (see, for example, the NASA programme described in last month's edition of this column) are not affected with regard to search strategy, because it would be difficult to transcend ourselves and cater to the viewpoint of an advanced extraterrestrial. However, the probability of contact not only depends upon our perspicacity in developing a search strategy, but their insight into our methods.

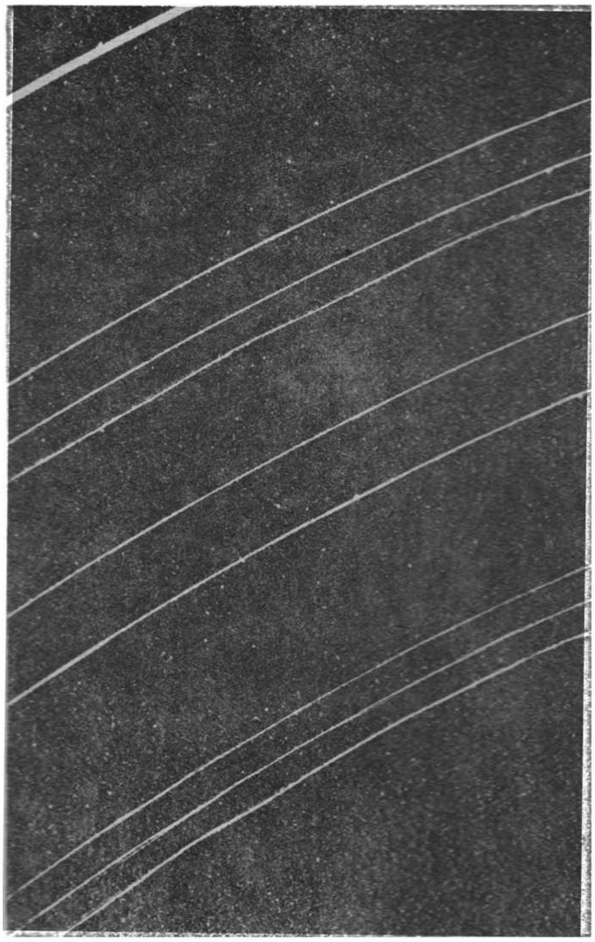
The interpretation of first contact does change. Instead of contact between peers, we would be the object of an experiment in animal psychology.



Voyager 2's wide-angle camera captured this view of the outer part of the Uranian ring system just 11 minutes before passing through the ring system on the morning of January 24 1986



Three of the newly discovered satellites of Uranus are captured on this image. All three lie outside the orbits of the Uranian ring system.

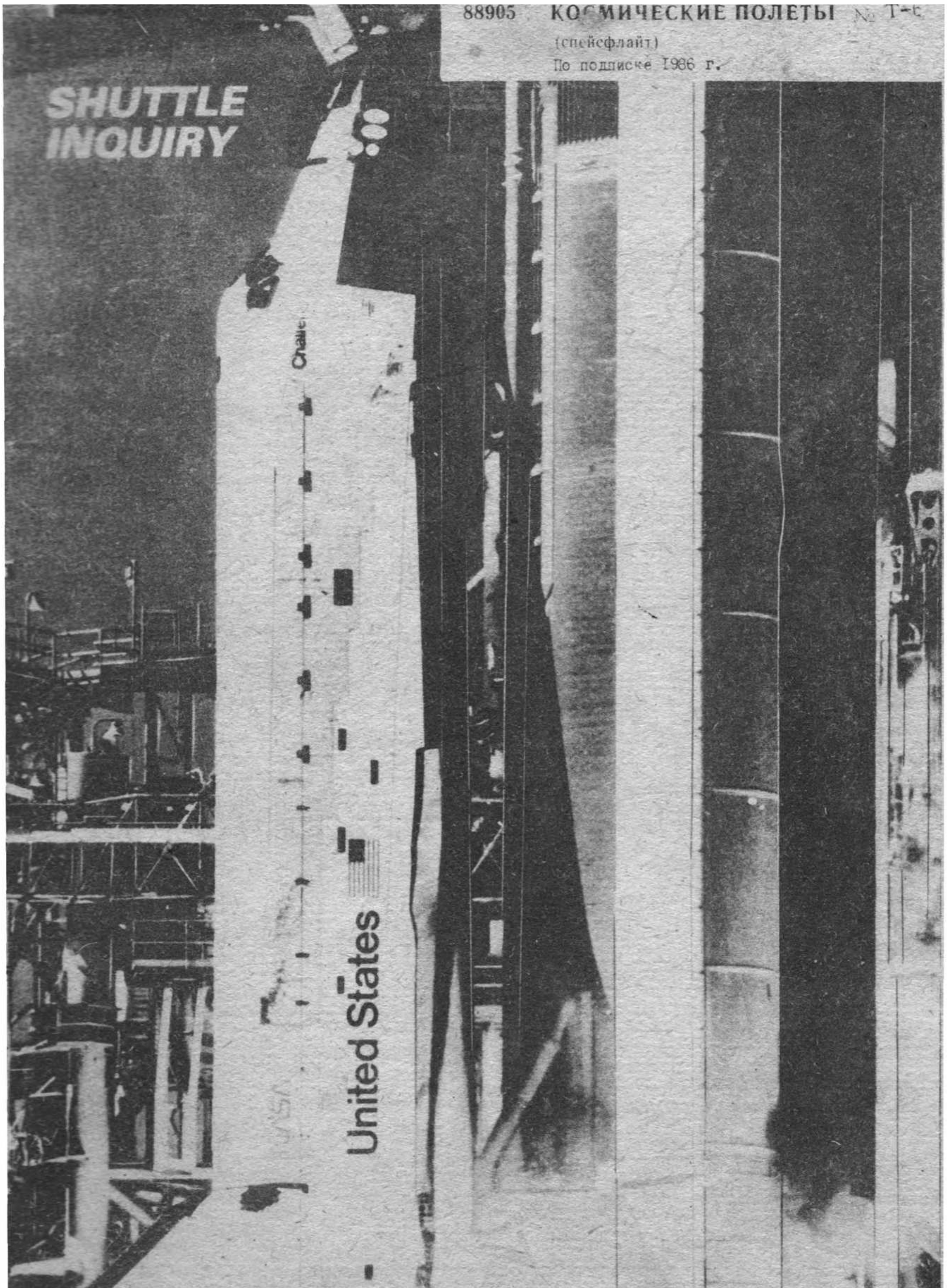


A newly discovered tenth ring of Uranus is barely visible near the top of this two-frame Voyager 2 mosiac. The tenth ring is about mid-way between the brighter, outermost epsilon ring and the next ring down, called delta.

JUNE 1986

Spaceflight

The International Magazine of Space and Astronautics



Vol. 28
No. 6

CONTENTS

Editor:
G. V. Groves

Assistant Editor:
C. A. Simpson

Managing Editor:
L. J. Carter

Spaceflight Sales:
Shirley A. Jones

Advertising:
C. A. Simpson

Spaceflight Office:
27/29 South Lambeth Road,
London. SW8 1SZ. England.
Tel: 01-735 3160.

SUBSCRIPTION DETAILS

Spaceflight is available world-wide by annual subscription. The rate for 1986 (10 issues) is £30.00 (US$50.00) inclusive of surface mail delivery. Subscribers also receive the publication *Space Education* (two issues) at no extra charge.

Airmail dispatch of ***Spaceflight*** to non European countries is available at an additional cost of £1.50 (US$2.50) per issue (1986). Air Mail dispatch is effective for the next issue of ***Spaceflight*** with orders in hand on the 14th of any month.

Back issues of ***Spaceflight*** are supplied from available stocks at £2.00 (US$4.00) each, inclusive of surface mail delivery.

All orders with remittance enclosed should be sent to 'Spaceflight Sales' at the above address. Payment may be by sterling or dollar cheque made payable to 'BIS' or by GIRO (to account number 53 330 4008).

Spaceflight may also be received regularly by mail through membership of the British Interplanetary Society. Details of application are available from the Executive Secretary.

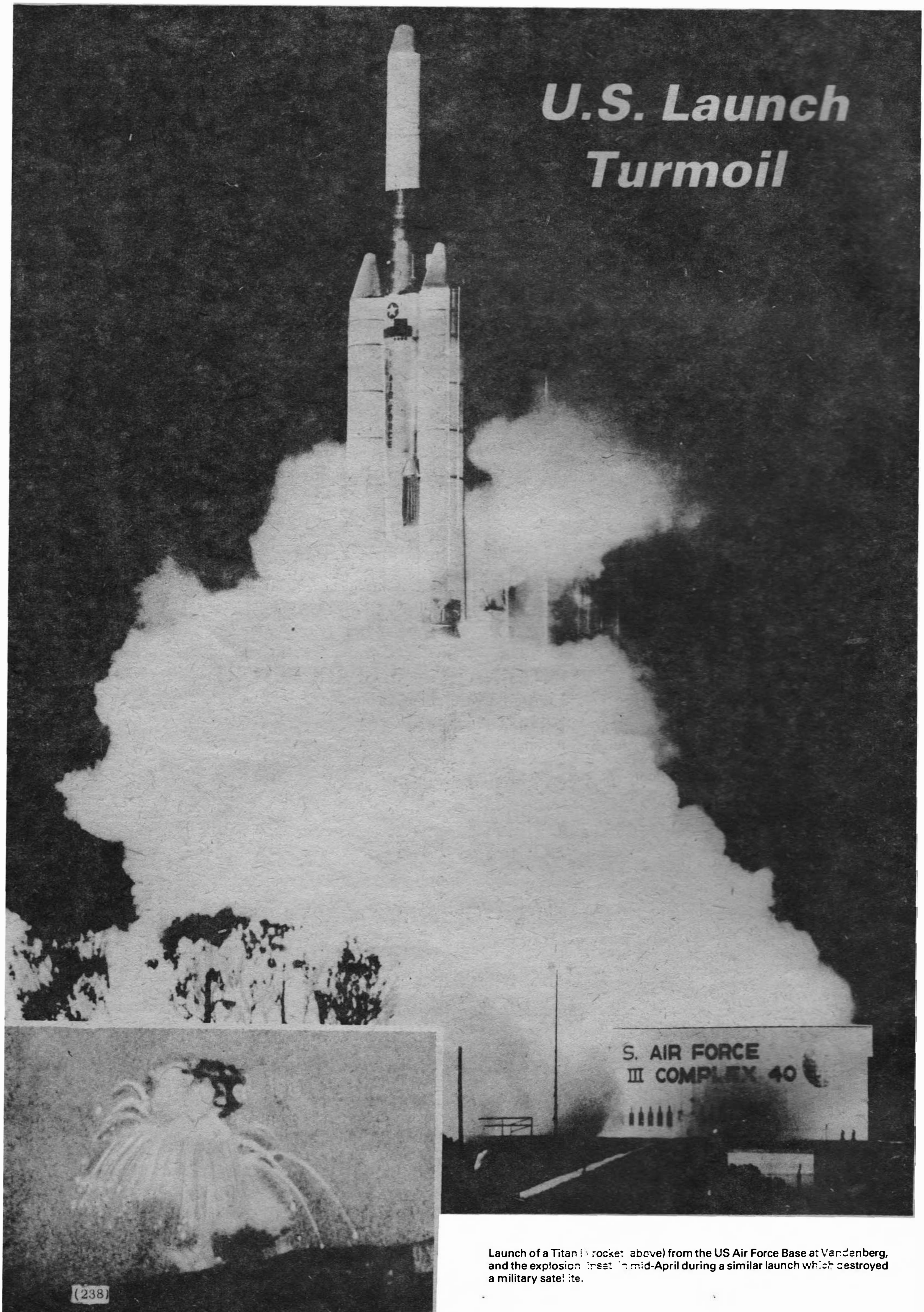
* * *

Published by the British Interplanetary Society Ltd., (No. 402498). Registered office: 27/29 South Lambeth Road, London, SW8 1SZ, England.

Vol. 28 No. 6 June 1986

Front Cover: Challenger at the moment of lift-off on January 28, 1986. Black smoke can be seen emitting from the lower section of the right solid rocket booster – indicating a serious failure at ignition. In this issue ***Spaceflight*** continues its coverage of the Shuttle Inquiry (page 240) and also looks at the problems facing the American Space Programme as a result of the latest launch accident.

U.S. Launch Turmoil



Launch of a Titan [illegible] rocket (above) from the US Air Force Base at Vandenberg, and the explosion (inset) [illegible] mid-April during a similar launch which destroyed a military satellite.

The American space programme is still in deep turm after three major launch failures during the first third ot 1986, a year that set out to be the most ambitious ever, when space flight would become routine.

First mission of 1986, launch of the modernised Space Shuttle Columbia, was a success, placing a commercial communications satellite in orbit and conducting materials processing research. It too, however, was plagued with delays, lift-off being postponed due to bad weather and technical problems a total of seven times.

Space Shuttle Challenger was due to conduct the next manned flight but mission 51L, the second of a record 15 flights planned for 1986 in the most ambitious Shuttle scheduling ever, ended 72 seconds into the flight on January 28 when a massive explosion led to the loss of all seven crew members.

The second disaster came in mid-April. This time a military satellite was lost just seconds after launch from Vandenberg when its unmanned Titan 34D booster exploded in a huge fireball.

Then, what should have been the routine launch of an important weather satellite in early May from Cape Canaveral turned into the nightmare NASA officials had not dare contemplate.

The Delta booster, in service for 26 years, made a perfect lift-off, powering the GOES satellite towards orbit. But with 70 seconds gone there was an un-explained main engine shut down and the rocket began to veer off course. Range safety officers had no option but to terminate the mission.

For space scientists and engineers striving to rebuild the American space effort in the wake of the Challenger tragedy and the Vandenberg disaster, the failure of the Delta rocket could not have come at a worse time.

With the Shuttle programme grounded until at least this time next year, the Titan programme expected to take between six and 12 months to recover, and a major set-back to the modest Delta manifest planned for 1986, American launch capability is severely restricted.

As far as the military is concerned the Titan 34D failure was compounded by the loss of a similar vehicle launched from Vandenberg on August 28, 1985.

The Titan 34D has now been launched a total of nine times, with the failures of last August and April 18 giving a success rate of 78 per cent. Investigations into the first loss revealed problems with the vehicle's turbo pump and a massive oxidiser leak. The April failure involved one of the solid rocket boosters which are mounted on the side of the core vehicle to provide 2.87 million pounds of additional thrust. However, the fault is not believed to be similar to the O-ring problem in the right SRB which led to destruction of the Shuttle Challenger.

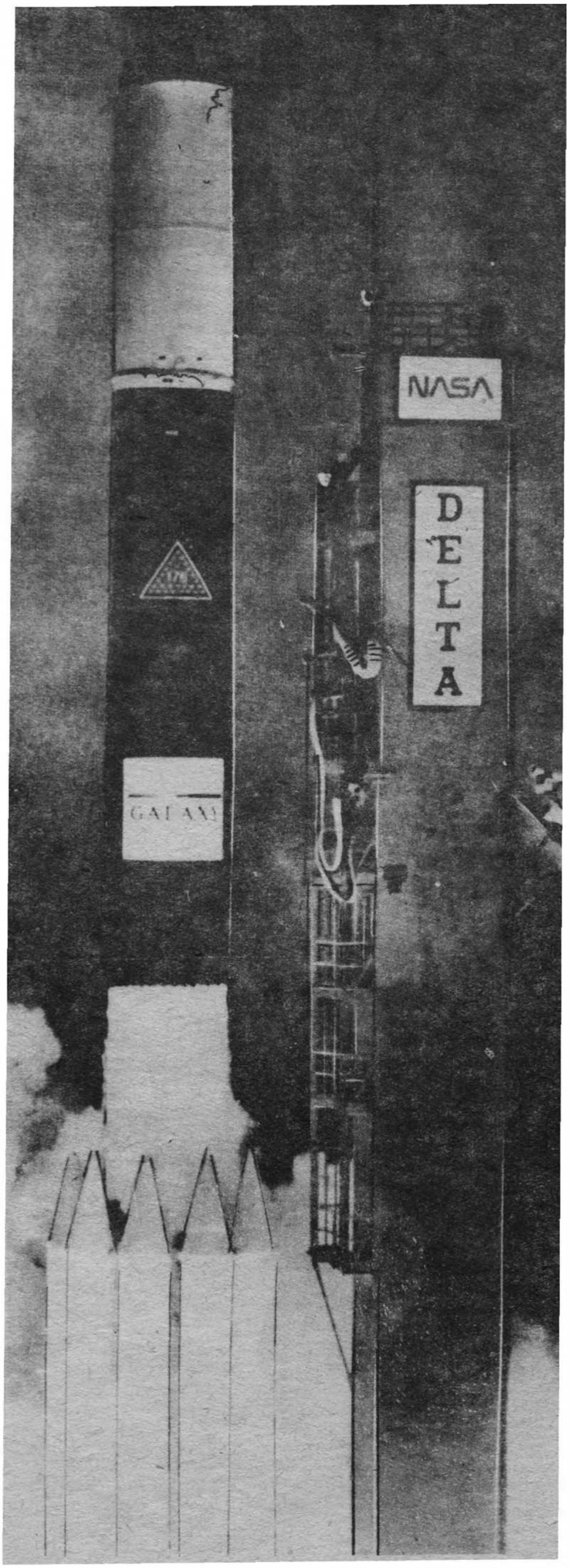
Launch of the GOES G weather satellite for the National Oceanic and Atmospheric Administration (NOAA) on May 3 was the first of three scheduled Delta launches from Cape Canaveral this year.

The Delta rocket had previously been launched successfully 43 times in a row without a major problem. It was travelling at about 1,400 mph and was 30 miles down range when the shutdown occurred. The flight to that point had appeared normal, with the first set of solid rockets correctly jettisoned at the 65-second mark.

But after the shutdown, the powerless rocket began to drift off trajectory, subjecting its nose to overwhelming aerodynamic pressures, as the nose lifted, its faring, or shield, began to break off, spraying the debris picked up by the cameras. Just over 90 seconds into the flight a NASA safety officer sent the command to destroy what was left of the now cartwheeling rocket.

The satellite was carrying a new Satellite Aided Search and Rescue system (SARSAT), an experiment to assist ships and aircraft in distress. The experiment was being conducted jointly with Canada, France, Norway and the Soviet Union and was to have aug-mented an international search and rescue system which has already helped save 525 lives since it began operations in September 1982.

GOES G was to have been the seventh meterological satellite belonging to NOAA and would have been placed into geosynchronous orbit at 75 degrees west longitude.



The McDonnell Douglas Delta rocket seen here on one of its previous 178 successful launches. Prior to the May 1986 accident the booster had flown 43 times without a hitch.

SHUTTLE INQUIRY – Commission Set To Report

The first months of 1986 dealt a cruel blow to the American space programme. In this special seven page report *Spaceflight* continues its extensive coverage of the events and discussions that have followed the Challenger disaster, leading up to publication of the official Presidential Commission inquiry report.

The Presidential Commission set up to look into the Challenger disaster began taking evidence in early February only a few days after the ill-fated launch.

President Reagan gave it 120 days to complete the awesome task of investigating the accident and coming up with the necessary recommendations to ensure a safe future manned space programme.

NASA personnel, astronauts, scientists, engineers and industry managers are among those to have given evidence before the Commission which is due to report at the beginning of this month.

Already it is clear that there must be a strong restructuring of management and lines of communication between all levels of NASA and its industrial contractors. It quickly became apparent during the Inquiry that not everyone was aware of concerns that should have prevented the launch of Challenger.

The recommendations will cover both technical and administrative aspects of NASA's space programme.

During early April findings on the break-up of the Shuttle based on analysis of wreckage were presented to the Commission by the National Transport Safety Board's (NTSB) Bureau of Accident Investigation.

Key points of the findings included:

•Collision damage to the front end of the right SRB and external tank. The conclusion from this is that the leaking booster broke free at its lower attach point forcing its nose into the side of the external tank.

•It is now thought that this impact at the forward end of the tank and a simultaneous rupture towards the rear did not cause a powerful explosion but broke up the tank quickly resulting in the mixing of the oxygen and hydrogen propellants as they became free.

•Although it was originally believed that Challenger was destroyed in the explosion the NTSB data points to the orbiter breaking up mainly due to excessive aerodynamic loads.

Loss of the right SRB and tank caused severe imbalance to the climbing stack, overstressing the orbiter as it tumbled uncontrollably. Examination of the wreckage points to minimal explosive damage to Challenger's structure.

•Wreckage analysis and computer enhanced pictures of the explosion have shown that the orbiter's cockpit section was severed and was mostly intact at water impact. It is therefore possible that the seven crew members may have remained conscious as the module plunged for between three and four minutes towards the ocean. Wreckage of the crew compartment recovered from the ocean floor shows severe water impact damage.

NASA launched 24 successful Shuttle missions before the Challenger explosion and records show that SRB O-rings were affected on 14 flights. The O-rings and special putty are designed to keep gas and flame within the booster.

Of the 14 flights primary O-rings were affected 22 times; secondary O-rings were damaged twice, soot was detected six times between the primary and secondary O-rings; and the primary O-rings was affected four times by heat but not damaged.

NASA has used higher performance boosters on 17 flights, beginning with STS-6 on April 4, 1983 and of these 12 experienced O-ring damage.

Re-design of the SRB joints is being managed by the Marshall Space Flight Center. A key modification will involve a mechanism designed to prevent joint rotation from unseating the O-ring seals during ignition. In the old design it was possible for internal booster pressure to stretch the joint and unseat the backup O-ring.

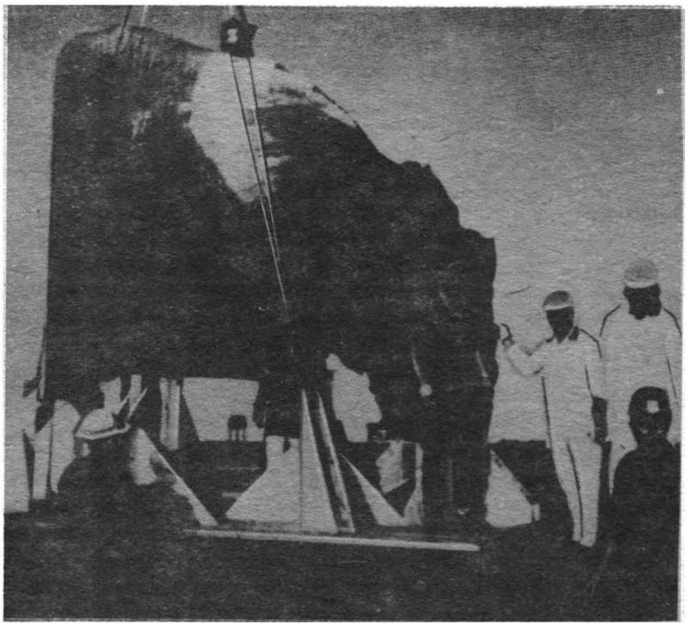
A further change will allow for the seals to be put in place during final installation, rather than using ignition pressures to seat them.

The putty – used to transmit pressure to the seals – will be removed altogether and replaced by overlapping insulation layers within the motor. These insulation layers would eliminate the need for the initial thermal protection provided by the putty.

Tests carried out since the Challenger accident have shown the putty performing in a random manner, with changes in temperature and humidity adding a degree of unpredictability to the putty's strength.

The exceptionally cool temperatures of the Challenger launch are believed to have seriously compromised the performance of both the putty and seals, so the new design will incorporate electrical heaters within an externally mounted weather strip around each joint. Such a strip would also minimise the possibility of rain penetrating the joint and subsequently freezing during prolonged exposure to cold weather.

A segment of the Shuttle's right hand SRB from mission 51L after recovery from the ocean. This picture shows the jagged edge where the aft joint ruptured.



Astronauts Unaware of Joint Problems

***Spaceflight* (May 1986) has already reported extracts of testimonies of key personnel in the Shuttle programme who have given evidence to the Presidential Commission inquiring into the loss of Challenger.**

Further important testimonies were provided by astronauts involved with the Shuttle programme, including John Young, Robert Crippen, Paul Weitz and Henry Hartsfield, who have notched up a total of nine flights between them.

The astronauts' views provided a major input to the final Inquiry recommendations and below* Spaceflight *publishes transcript extracts from these testimonies, which cover the increasing pressure to fly more and more missions, breakdown in management communication, possible abort systems and landing safety.

John Young (chief of the astronaut office): "Last year was an incredibly good year for the space programme. We flew nine Space Shuttle missions, which was four more than we flew in '84 and we almost flew 10. We were working about as hard as this system can work last year."

William Rogers (commission chairman): "Did at the end of 1985 you feel or the office feel that you had had too much to do in 1985?"

Young: "It was hard for me to see how we could do a lot more. People were working long hours and they were working long periods of time, and I'd like to say we could do more missions than that but from an operational standpoint it'd be tough."

Robert Hotz (commission member): "How do you view the 15-launch schedule for this year as far as a load on your system?"

Young: "I think it would have been pretty tough."

Rogers: "In the event of a problem with the (solid rocket booster) joint . . . I'm trying figure out how that information gets to the astronaut community, and I gather in this case it didn't. And the information about the joint that failed and we think probably caused the accident was not known to any of you gentlemen, as I understand it."

Paul Weitz (Young's deputy): "That's true, which means therefore that if it surfaced at one of these meetings (of the flight crew) . . . either we were not made aware of it while we were there or we did not realise the significance of the item."

Rogers: "How did it happen that the astronauts who are so vitally concerned with the safety aspects didn't know about this problem?"

Weitz: "That's part of what we're trying to reconstruct also."

Rogers: "We realise you're not going to be aware of every single problem. But certainly critical ones like this that have gotten to the point where a redesign is under consideration, it's difficult for us to understand why you didn't know about it. And I can see why Mr. Young and the others were upset about it."

Weitz: "The system was in place but it broke down in some way. I think part of the message that comes across here perhaps is that we do not have enough people in the office to be intimately involved in all of these details along the way."

Robert Crippen (astronaut and deputy director of flight crew operations): "The astronaut office is intimately involved with all phases of the program. The flight readiness review occurs approximately one to two weeks prior to flight. One of the prime things we do in a flight readiness review is review the anomalies that have occurred on previous missions and decide how we have resolved those or why we think it is acceptable to go fly with those. And specifically in mentioning the joint problem, I was the participant representing the flight crew operations. On Mission 51B, (an April 1985 Discovery mission) which was the mission that we flew right after 51C (a January 1985 Department of Defense mission flown by Discovery) where we did have a blow-by problem, that was presented. In truth, from my perception, it wasn't considered that much of a big deal. And it wasn't like we had a major catastrophe awaiting in front of us."

He was then asked to explain who had presented the anomaly.

Crippen: "That was presented by the Marshall Space Flight Center in going through their stuff on the solid rocket boosters. It was presented as an anomaly. We had had a putty change on the joint just prior to that and it was alluded that perhaps the putty modification may have had something to do with that, but that it really wasn't that big of a deal.

"We're flying crews of normally five people from the astronaut office and my personal experience has been probably the most knowledgeable people on the center with the payloads were in the crew.

"Our flight crews probably understand it as good as any person possibly could when you look at the overall system. They rely very heavy, as we always have, on our systems division people who monitor each system specifically but everyone is not bashful about picking up the phone and saying, 'Hey, come talk to me about

Continued on Page 243

This communication from Joe Kilminster (vice president of Morton Thiokol's booster programmes) was sent to Kennedy Space Center and Marshall Spaceflight Center the night before the January 28 launch. It recommended lift-off proceed but warned that hot gas could pass through the primary O-ring seals.

MTI ASSESSMENT OF TEMPERATURE CONCERN ON SRM-25 (51L) LAUNCH

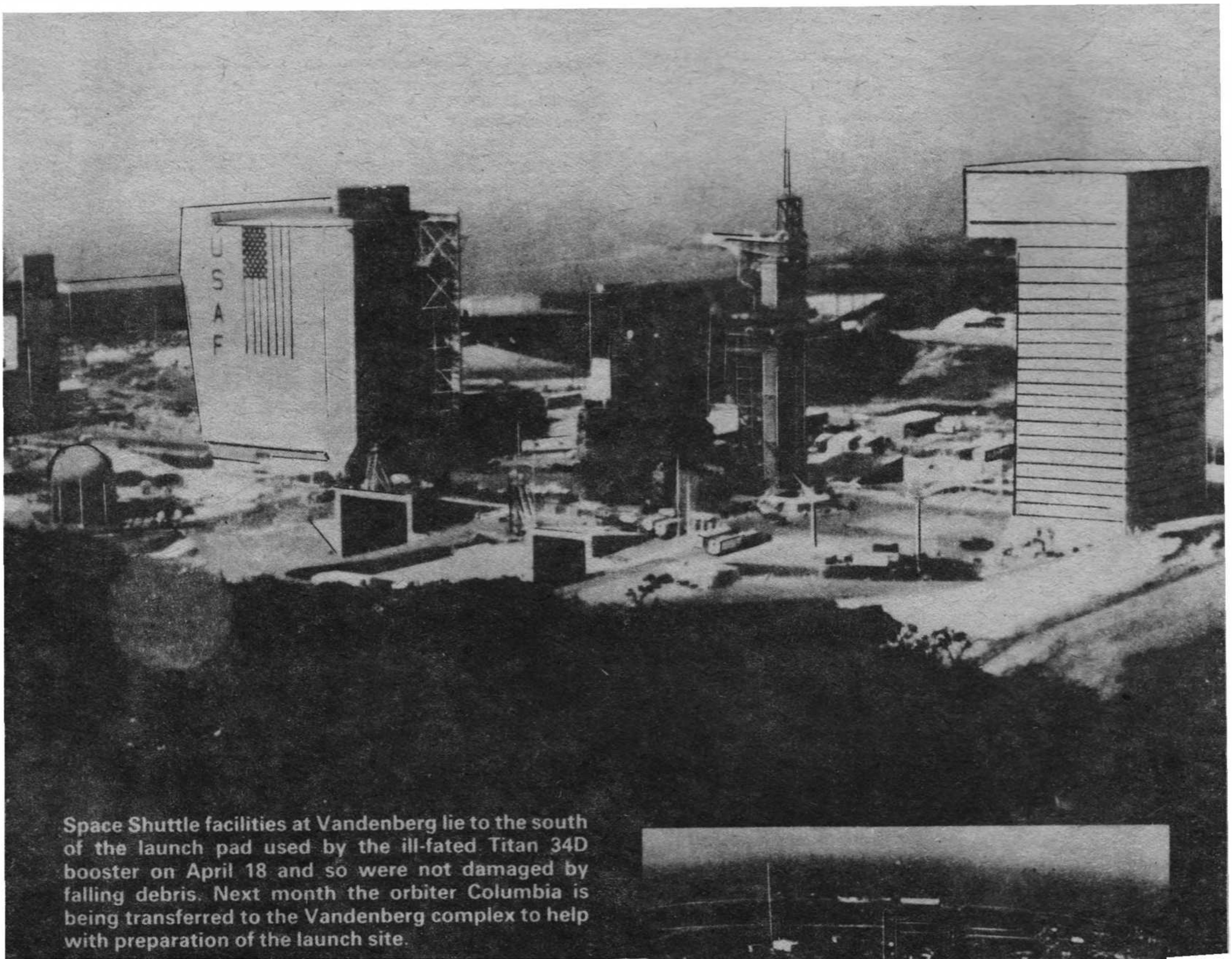
- O CALCULATIONS SHOW THAT SRM-25 O-RINGS WILL BE 20° COLDER THAN SRM-15 O-RINGS
- O TEMPERATURE DATA NOT CONCLUSIVE ON PREDICTING PRIMARY O-RING BLOW-BY
- O ENGINEERING ASSESSMENT IS THAT:
  - O COLDER O-RINGS WILL HAVE INCREASED EFFECTIVE DUROMETER ("HARDER")
  - O "HARDER" O-RINGS WILL TAKE LONGER TO "SEAT"
    - O MORE GAS MAY PASS PRIMARY O-RING BEFORE THE PRIMARY SEAL SEATS (RELATIVE TO SRM-15)
      - O DEMONSTRATED SEALING THRESHOLD IS 3 TIMES GREATER THAN 0.038" EROSION EXPERIENCED ON SRM-15
  - O IF THE PRIMARY SEAL DOES NOT SEAT, THE SECONDARY SEAL WILL SEAT
    - O PRESSURE WILL GET TO SECONDARY SEAL BEFORE THE METAL PARTS ROTATE
      - O O-RING PRESSURE LEAK CHECK PLACES SECONDARY SEAL IN OUTBOARD POSITION WHICH MINIMIZES SEALING TIME
- O MTI RECOMMENDS STS-51L LAUNCH PROCEED ON 28 JANUARY 1986
  - O SRM-25 WILL NOT BE SIGNIFICANTLY DIFFERENT FROM SRM-15

Joe C. Kilminster

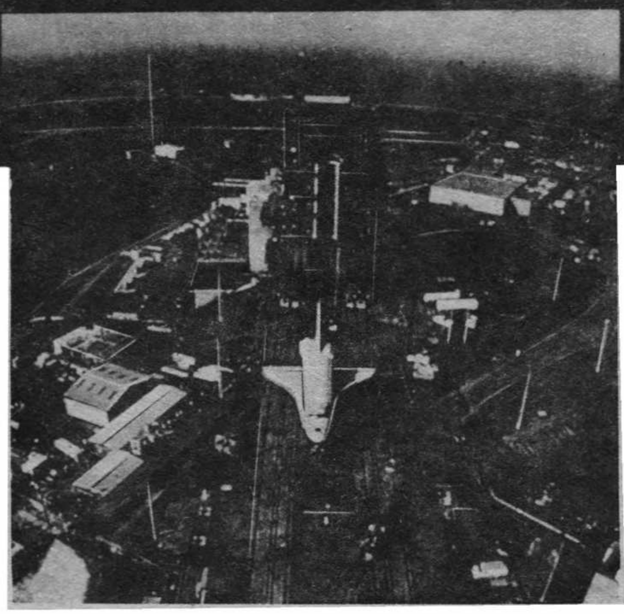
JOE C. KILMINSTER, VICE PRESIDENT
SPACE BOOSTER PROGRAMS

MORTON THIOKOL INC
Wasatch Division

FAXED TO:
MSFC. # 205-453-5725
KSC # 305-867-7103
9:45 PM MST
27 JAN 1986



Space Shuttle facilities at Vandenberg lie to the south of the launch pad used by the ill-fated Titan 34D booster on April 18 and so were not damaged by falling debris. Next month the orbiter Columbia is being transferred to the Vandenberg complex to help with preparation of the launch site.



COLUMBIA TO SUPPORT VANDENBERG TESTS

NASA plans to ferry the orbiter Columbia to Vandenberg Air Force Base, California in mid-July to support launch site validation testing in preparation for the first west coast Space Shuttle flight.

Presently at the Kennedy Space Center undergoing postflight servicing and a series of modifications, Columbia is expected to remain at the California launch site until early November.

Testing will closely parallel that which was performed at Kennedy Space Center prior to Columbia's first flight on the maiden Space Shuttle mission in April 1981.

Columbia will be flown to Vandenberg AFB atop the modified Boeing 747 Shuttle Carrier Aircraft. Initial processing to remove ferry flight equipment and ready the ship for vehicle stacking will be performed at the Orbiter Maintenance and Checkout Facility.

Columbia will then be moved to the launch pad and mated with a set of solid rocket boosters and an external tank for integrated vehicle testing that will include the loading of cryogenic propellants in a "wet" countdown demonstration test.

No Flight Readiness Firing is planned during this phase of Vandenberg site testing but such a test firing, like those performed at KSC, is planned as part of the build up to first launch.

Processing on Columbia at KSC over the last two months has included installation of main engines, auxiliary power units, and orbital manoeuvring system pods in parallel with structural inspection, approved modifications, and ferry flight preparation.

The decision to assign Columbia to near-term Vandenberg site validation testing allows time for extensive modification at KSC on Discovery, which is allocated to the west coast missions.

Discovery will remain at KSC over the summer undergoing modifications to equip it for Centaur missions, completing planned wing structural strengthening, and installation of additional test instrumentation desired for the initial Vandenberg launches.

this' and sit down and go over any details of any problems. We normally have the anomaly list from a flight to go through as soon as that flight is over.

"So I don't want to leave the picture that... the flight crew is off there training and they don't know anything about what's going on down in the bowels of the ship. That is not correct."

Rogers: "There was some mission management team meeting on the 27th of January, the day before the launch. It was 2 pm on January 27th, and at that time Arnold Aldrich (Shuttle programme director at Johnson Space Center) said there was a concern about the weather the next day and he advised everyone at that meeting that if they had any problems, any concerns about the weather, let him know. And as the testimony disclosed, he was not advised about the O-ring, the joint problem and the weather as it related to that joint. And my question was any astronaut present at that meeting?"

Weitz: "Yes sir, I think I was."

Rogers: "All right. Then at the 9 o'clock meeting the morning of the launch, were you there, too, Mr. Weitz?"

Weitz: "Yes sir."

Rogers: "And you remember that Mr. Aldrich advised for people at those meetings that any concerns about the weather, he should know about and he should be told about them?"

Weitz: "Yes."

Rogers: "And he wasn't, apparently."

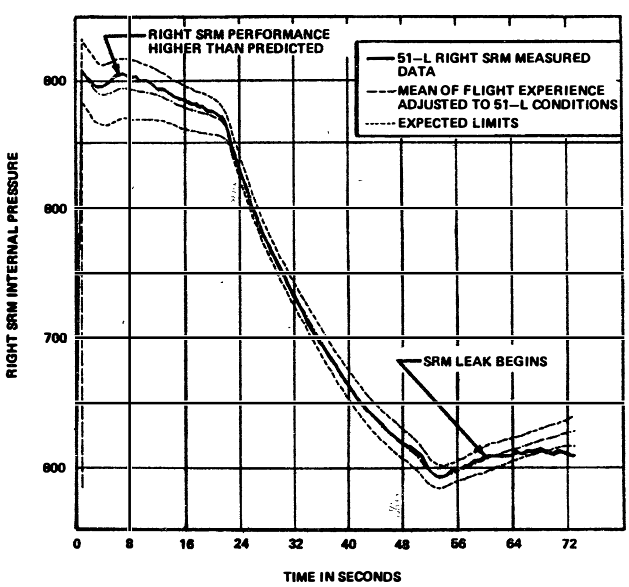
Weitz: "Well, the meeting . . ."

Rogers: "I was speaking about the weather as it relates to the joints, the O-rings."

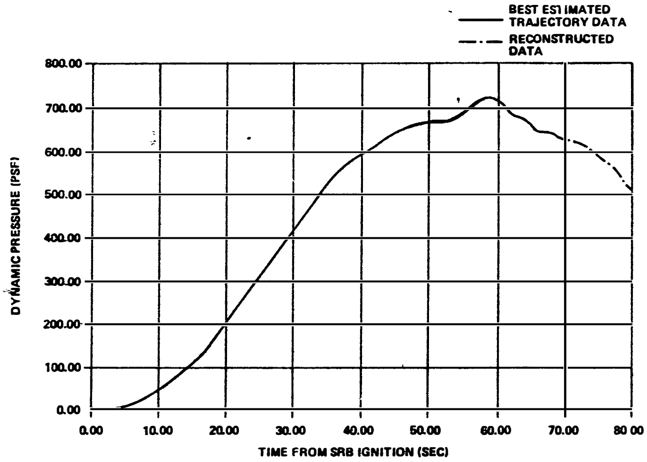
Weitz: "No sir, We were not aware of any concern at all with the O-ring, let alone the effect of weather on the O-rings."

Rogers: "So he was not nor were you advised of all the problems that existed in the minds of the people at Morton Thiokol (manufacturer of the solid fuel booster rockets) and the people at Marshall Space Flight Center about weather. Neither you nor Mr. Aldrich was advised about that?"

Internal pressure of the right Solid Rocket Booster during ascent.



Comparison of reconstructed and best estimated trajectory dynamic pressure profile for Challenger, 51L.



Weitz: "Not that I remember at those meetings, no sir."

The astronauts were then asked if they had detected an unusual urgency to proceed with the launching, out of the pattern of prior launches they had experienced.

Young: "I think there is an urgency to proceed with every launch once you get a vehicle loaded and on the launch pad. I don't see anything wrong with that. But it's there and I think in the future the higher the launch rate the more of that urgency exists and I'm not sure that's something we have a whole lot of control over, but I think we ought to watch it very carefully."

The question was pursued and again the astronauts were asked if there was an unusual urgency surrounding this launch.

Weitz: "I didn't perceive any, did you?"

Young: "I did not perceive any different sense of urgency with this one as with any other."

Weitz: "There is a general feeling that once you start into the count, a lot of work has gone to get you out to launch morning and you would like to within reason to those things necessary to get the launch off. But . . . if you are asking for perceived differences, I did not perceive any."

* * *

Henry Hartsfield (astronaut): "Safety is the watchword. That's the thing that's foremost in all of our minds because really, if you're safe, then that equates to a successful mission.

"The first thing I think we ought to do, and we are doing, is re-evaluate the design. For example, it doesn't make much sense to build a wing that's good for four Gs and a tail that will fall off at two Gs.

"I personally would like to see some sort of . . . escape system . . . some ability to bail out of the vehicle. I personally don't think the vehicle will survive a ditching. When you talk about spiking the water at 200 knots with an airplane that's basically an airliner-type design, I'm convinced that it's going to break up. And if you've got a 6,000 pound payload behind you, it's probably going to come into the cockpit with you.

"Whether we can develop such a thing reasonably or not I'm not sure, but there are options that I'd like to see us look at."

Young: "I really believe that manned space vehicles, if

we don't do it for this one, then surely the next vehicle that we develop, there should be an escape system. It's not going to be a cheap-type quick fix, I don't think, to give you any reasonable chance for escape."

Crippen: "I don't think I know of an escape system that would have saved the crew from the particular incident we just went through. I don't think it's possible to build such a system."

They were asked if it was feasible to provide for an abort system in the fourth Orbiter, if one is built.

Weitz: "You have three alternatives: escape module, rocket assisted escape system or some sort of bailout. You cannot modify the existing Orbiter to accommodate an escape module, so therefore we've considered these other two methods.

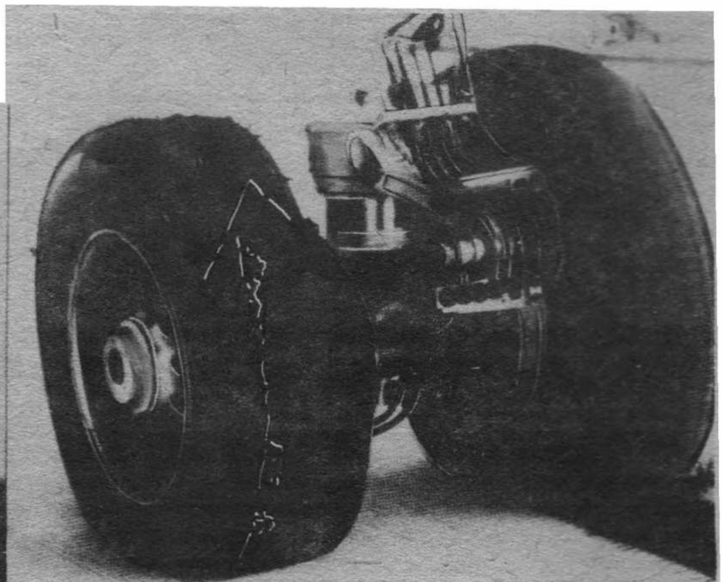
"John likes the rocket extraction system because it does cover a wider flight regime. It allows you to get out perhaps with the vehicle only under partial control, as opposed to complete control. However, when you add more parts it gets more complex. With a bailout system you have to modify the side hatch or the top hatch, depending on which you want to go out. But that says that you obviously have to be subsonic in stable flight."

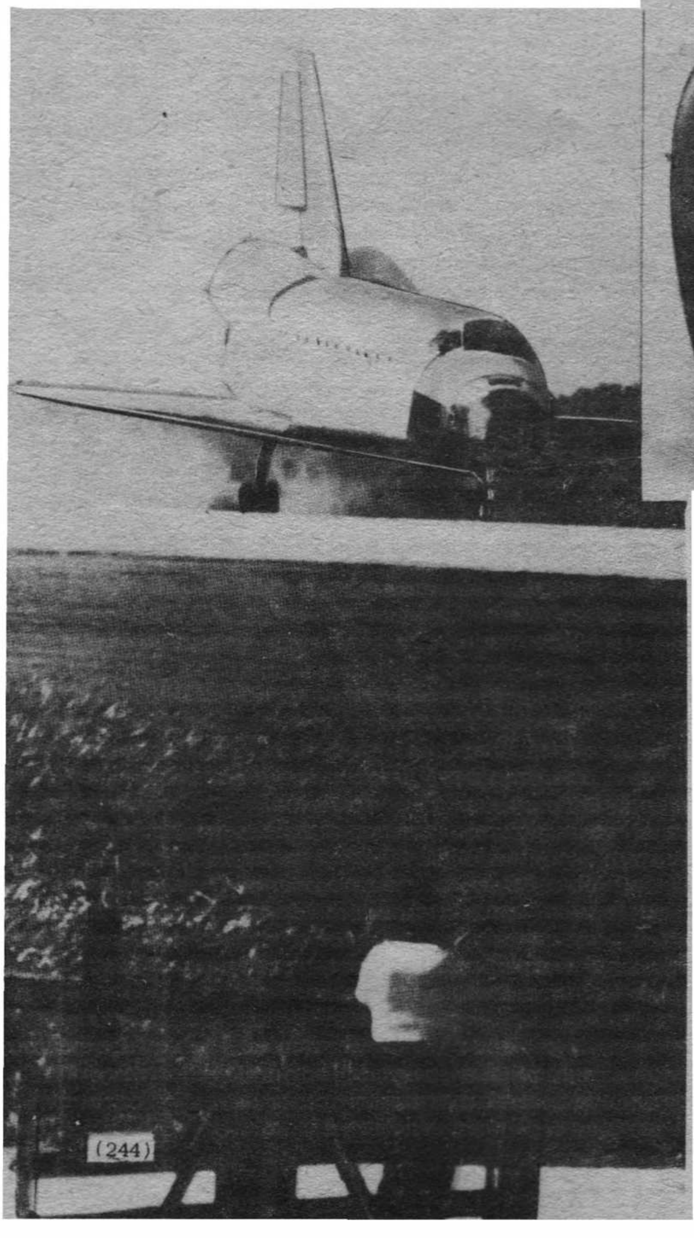
Crippen: "I am for building a fourth Orbiter . . . but I consider it very much important that we keep the configurations of the vehicle the same. It is a real problem, and we've seen this previously, any time we get multiple configurations between vehicles, we've got a training systems problem that is phenomenal. And somehow, it doesn't make much sense to me that we'd end up with one vehicle that has an escape system on it and three that didn't."

Hartsfield: "I'm in the process of re-evaluating our training. About two thirds of the crews that have flown so far have made statements they felt there was a time compression in the training the few weeks before flight. We are looking at what we can do to offload this work period so that the crew doesn't go fly tired. Some of us have some concerns that maybe this load is getting on the high side.

"The thing that I think is really the key in the accident . . . that's communications. Apparently we had some sort of breakdown that the word about the seals didn't

Everything appeared normal as Discovery touched down on the KSC runway (below) on April 19, 1985 but then the brakes on the right landing gear locked, blowing one tyre and shredding the other (right.)





KSC LANDINGS AND ATTEMPTS

- June 24, 1983 – The first planned landing at KSC is cancelled because of bad weather. The Shuttle Challenger is forced to land at Edwards Air Force Base, California.
- Feb. 11, 1984 – Challenger becomes the first spacecraft to land at its launch site, touching down on the KSC runway at 7:17 am.
- Oct. 13, 1984 – Challenger lands at KSC after an eight-day mission, touching down at 12:26 pm.
- Nov. 16, 1984 – Discovery, on its second flight, lands at KSC at 7 am.
- Jan. 27, 1985 – Discovery lands at KSC at 4:23 pm after completing the first Department of Defense Shuttle mission.
- April 19, 1985 – Discovery's brakes lock and a tyre blows out during its 8:55 am landing at KSC. It is the last landing at KSC.
- Jan. 6, 1986 – Space Shuttle Columbia's landing, the first scheduled at KSC following the April mishap, is delayed three times because of bad weather. Columbia finally lands in California.

get to the right places. We've got a very good system, but it's only as good as the data that gets into it."

Rogers: "The people at Marshall, they complain of the system. They say, 'We had no obligation under the system to do anything we didn't do. It was a Level 3 question. . . we worked it and therefore we didn't have any responsibility under the system, that's wrong?' That's not a good system."

Hartsfield: "The system as we work it on our "op" side is good but this part of the channel apparently was broken. We are going to correct that.

"We'd like to see some sort of an independent safety panel effort that . . . provides an independent channel for those things . . . somebody that's not worried about programatic issues or anything, but just thinking safety."

Rogers: "One of the things that we're thinking about recommending is some kind of independent safety panel. We think it's very important. We're not quite sure how that should be set up, but I think all of us believe there should be an independent safety review panel of some type."

Richard Feynman (commission member): "I tried to figure out where the difficulty is in this system that made it go wrong. The problem is communication, and that communication will be fixed if you have the safety panel if there's a member of the astronauts on the safety panel because then you'll be fully aware of all the things that are unsafe. So the communication problem and the safety panel will automatically fix each other with regard to an understanding of what the real risks are.

"You decide what risks to accept. And I've read all these reviews and they agonise whether they can go even though they had some blow-by in the seal or they had a cracked blade in the pump of one of the engines whether they can go the next time or this time. And they decide yes. Then it flies and nothing happens. Then it is suggested therefore that that risk is no longer so high. For the next flight we can lower our standards a little bit because we got away with it last time.

"An argument is always given that last time it worked. It's a kind of Russian roulette. You got away with it. There was a risk but you got away with it. But it shouldn't be done over and over again.

"When I look at the reviews I find perpetual movement heading for trouble, so I would like to know if by the safety review board you mean this: that there should be . . . a permanent . . . safety board . . . which rides hard on that difficulty and tries to get rid of it as quickly as possible. I think we haven't got a direct action positive activity, someone whose responsibility is to work as hard as possible to keep everybody awake."

* * *

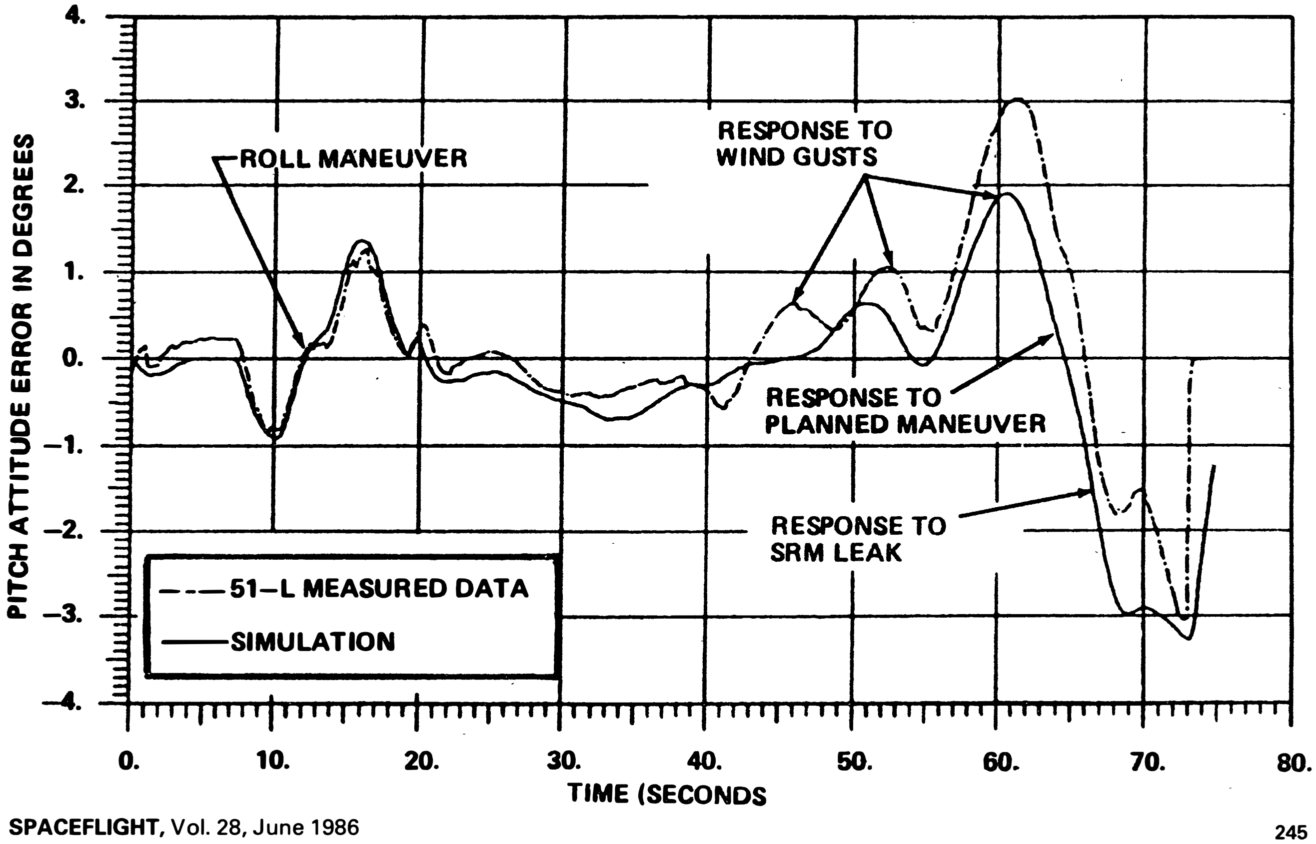
Young: "We've been talking about some concerns that we've had in the astronaut office for many years and one of them is the prudence of landing the vehicle at Edwards (Air Force Base, in California) and Northrup (at White Sands, N.M.) strip complexes.

"I'm a Florida boy myself and I always thought the programme should land the Orbiter at Kennedy Space Center, and over the past five or six years we've come to some very different conclusions based on learning about the environment that exists and learning about the limitations of the Orbiter we have in that environment.

"One significant difference in Florida is difficulty of accurately forecasting the occurrence of thunderstorms, fogs or crosswinds for an end-of-mission landing. The Orbiter requires much better weather than you would imagine to be able to make reasonable approaches and landings.

"We have a brake system on the Orbiter that is sort

Reconstruction of flight dynamics for Challenger, 51L.



of very difficult to use precisely right now. We're finding out we don't really have a good technique for applying the brakes. At Kennedy, the runway surface is very rough. In a high crosswind, it tends to scrape the cords off the tyres and that's very hard on tyres. The runway is surrounded by a moat and, depending on how much rain you had, the water could be pretty close to the runway. It doesn't meet Air Force runway standards. If you have certain failures it's going to be very difficult to make the runway.

"We just think it'd be more prudent and safer for the programme to take this vehicle and land it at the runway complexes (in California and New Mexico) for end of mission. I think it would avoid some of the risk associated and make sure we get the vehicle back every time. We know we spend a lot of programme resources building up the Kennedy system and making it possible for us to land there, and that we do have to land there at times, that we have return to land site abort because there's just nowhere else. But if we ever run off the runway at Kennedy the repair bill is going to be probably enough to build five or six more runways there at Kennedy."

Rogers: "Is it safe to land the Orbiter at Kennedy if it's raining?"

Young: "The runway is highly grooved so it might be safe. But if you ever went through a rain like that, you're not going to save yourself any turnaround time because you're talking about many days . . . to repair damage to the heat-resistant tiles on the Orbiter."

Rogers: "What choice do you have once the decision is made to land at Kennedy? You have an hour an a half to go. Is there anything you can do during that hour and a half period if the weather changes? Once deorbit occurs, is there any option left?"

Young: "No, sir. It's not like an airplane where anytime you go somewhere in bad weather you always have an alternate. You're committed to land on one end of the runway or the other end of the runway. You can swap runways . . . about 12 minutes prior to landing, but that's about the extent of your capability."

Crippen: "I don't think you'll get any pilot in the astronaut office who'll disagree with the premise that you're much safer landing at Edwards. There's some things you could do to make Kennedy better, but you're never going to overcome the weather unpredictability."

Young was then asked if part of his job had been to learn about concerns of astronauts and to express them to the system and to express his own concerns, and did he feel those concerns have been properly and appropriately handled by the system?

Young: "Sometimes yes and sometimes no."

Questioner: "You're satisfied then that the concerns that you've expressed in the past and the ones that you may have on your mind today are being properly considered under Adm. Richard Truly, head of the Shuttle programme?"

Young: "Yes, sir. And I think that's going to be an ongoing process for a long, long time."

Questioner: "What kind of an engineering effort is ongoing on the brake problem and is it a matter of technology or money to fix it?"

Young: "It's a matter of money."

George Abbey (director of flight crew operations): "As we tend to attempt to fly more frequently, I think we need to look at a better check and balance in the system. And John and I have talked quite a bit, we've talked to other people about looking at establishing a more independent safety organisation within NASA, and within the center."

Young: "The very biggest problem that must be solved before the Space Shuttle flies again is communications . . . early identification and proper appreciation of programme-wide safety issues.

"That NASA internal working paper on Space Shuttle flight safety, the one that I wrote . . . covered several concerns that are safety issues. And each of those concerns is being dealt with right now. Prior to the accident, many of these safety issues were . . . in the system but they were not being worked and I was told mainly because we didn't have the money to deal with them. That's a worrisome condition to me and it needs to be corrected . . . but it in itself is kind of a communications problem because I didn't know some of those were in the system.

"I wonder sometimes why, if the Space Shuttle is inherently risky why we should accept additional avoidable risks in order to meet launch schedules, and we do that sometimes.

"One of the problems we have is to get a communications link and properly define those risks. Furthermore, we need a foolproof way to surface to the top and correct safety issues early so that we can prevent another accident."

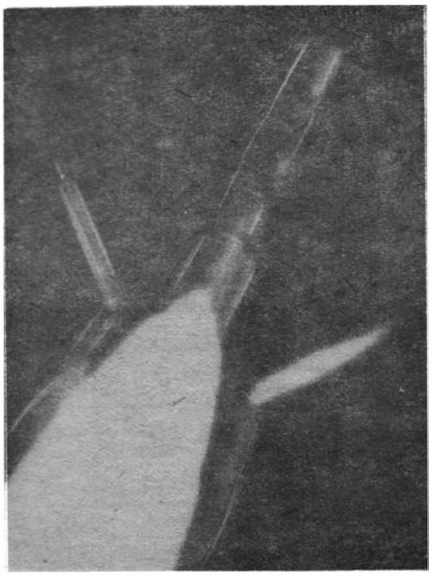
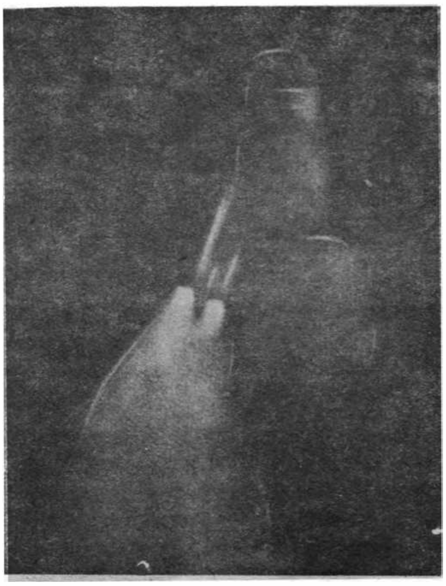
Questioner: "Have you collected your thoughts yet on what you think is the cause of the lack of communication which we've seen and which everybody's worried about?"

Arnold Aldrich (Shuttle programme director at Johnson Space Center): "There were two specific breakdowns, at least in my impression, about the situation. One is the situation that occurred the night before the launch and leading up to the launch . . . I can only conclude what has been reported, and that is that the people responsible for that work in the solid rocket booster project at Marshall believed that the concern was not of the significance that would be required to be brought forward because clearly the programme requirements specify that crucial problems should be brought forward to Level 2 and not only to Level 2 but through to myself at Level 1.

"The second breakdown of communications, however, and one that I personally am concerned about, is the situation of the variety of reviews that were conducted last summer between the NASA headquarters organisation and the Marshall organisation on this same technical area and the fact that that was not brought through my office in either direction . . ."

* * *

Spaceflight will be continuing its detailed report of the consequences of the Shuttle disaster with continued coverage of the Presidential Commission Board of Inquiry and the conclusions and recommendations that are to be issued shortly.


Picture sequence of the ill-fated Delta 178 launch on May 3, 1986. On a perfect spring evening, Delta 178 with the Geostationary Operational Environmental Satellite (GOES-G) on board rose from Complex 17-A at Cape Canaveral Air Force Station only to experience an abrupt first stage main engine shutdown at about 71 seconds into the mission requiring the vehicle to be destroyed by the Range Safety Officer 20 seconds later.

Left photo: **At about 66 seconds after launch the second set of solid rocket boosters is jettisoned as planned.** ***Centre photo:*** **At about 80 seconds after launch the vehicle tumbles out of control following the engine shutdown at 71 seconds.** ***Right photo:*** **At about 91 seconds after launch the vehicle is destroyed by the Range Safety Officer.**

Notebook From The Cape

by Gordon L. Harris

NASA has literally been torn apart in the weeks following Challenger's fiery death. For the first time since the agency was founded in October, 1958 astronauts publicly criticised its management. The occasion was a public hearing conducted by the Presidential Commission investigating the tragedy, chaired by former Secretary of State William Rogers.

Led by veteran John Young, chief of the astronaut office at Johnson Space Center, spokesmen for the corps of 95 pilots and mission specialists expressed their reservations about management of Shuttle programmes and launches, and urged more money, time and effort to ensure flight safety.

Within the agency's engineering cadre, too, sharp divisions have appeared, primarily at Marshall Space Flight Center in Huntsville, Alabama, responsible for the main engines, solid booster rockets and external fuel tanks. Arnold Aldrich, overall Shuttle manager at Johnson Center, criticised MSFC during a Commission appearance, so there is division between NASA centres as well as within the programme management structure.

★ ★ ★

While it largely escaped press notice (or understanding) Aldrich told the Commission of a major change in the way Shuttle business is conducted. In the past, he explained, the "design centers" like MSFC and JSC told their NASA counterparts at Kennedy Center what they wanted done to prepare Shuttles for launch, or to maintain them, or to install modifications or new components. Having transmitted those instructions, the "design centers" expected KSC and its major contractors to carry out orders. That has been drastically changed, Aldrich noted. Hereafter the "design centers" will directly supervise the work.

In effect, that sharply reduces the responsibility and authority of the launch team. KSC will provide the buildings and equipment where non-KSC managers will see to it that their desires are executed. It's about the same as long standing arrangements between KSC and the Goddard and Lewis Centers. Goddard manages Delta vehicle procurement and launches, and Lewis performs the same functions for Atlas Centaurs. While KSC employs a relatively small company of civil servants to coordinate the work of launch contractors and Air Force support contractors, managers from Lewis and Goddard actually make the go, no-go decisions.

A strong case can be made that this is an illogical, costly and essentially stupid way to run space launches. But it reflects built-in traditions and loyalties, political realities, and the inherent distrust by those who must relinquish their costly hardware to the tender, loving care of others they do not control. How long and at what price NASA must re-learn that lesson is impossible to foretell. It took the fire of Jan. 27, 1967 to straighten out management relations between "NASA West" in Houston and KSC. Now the Challenger explosion has apparently ruptured them one more time.

★ ★ ★

Some of the agency's current mishmash of troubles arose because of the absence of strong, central authority. James Beggs, the administrator, finally gave up his job to defend against government charges stemming from defence contracts awarded to General Dynamics, his former employer. William Graham sought to fill the void but it was obvious to one and all that he would not become a permanent boss. Instead the President chose James Fletcher, former administrator 1972-1979, but Fletcher could not take over until confirmed by the US Senate. So from late January until May, NASA floundered like a beached whale. Rear Admiral Richard Truly returned as associate administrator to head the Shuttle programme but he was not the administrator, even though some of his public pronouncements sounded so.

Whether Fletcher can do the necessary house cleaning within the agency's management to straighten out its problems remains to be seen. Meanwhile, there are three Shuttles awaiting whatever decisions emerge from the investigations and the White House and Congress must decide what to do, if anything, about reopening production lines for expendable vehicles. NASA long ago said the last of them would be fired in 1980 – a commitment which proved as over optimistic as its companion assurance – that the STS would carry all US space payloads.

2147

Mir Ready For New Crew

Leonid Kizim

Vladimir Solovyov

A Space first was clinched by the Soviets in early May when two of the country's most experienced cosmonauts, Leonid Kizim and Valdmir Solovyov, transferred from one orbital complex to another.

Kizim and Solovyov had completed more than 50 days on the new Mir Space Station, carrying out extensive engineering and systems checks.

The flight in Soyuz T-15 from Mir to Salyut 7 covered approximately 1700 miles and was seen by the Soviets as proving important ground for the future when perhaps several space laboratories or modules in close orbit will require servicing by cosmonauts.

Prior to the cosmonauts switching from Mir to Salyut 7 the two space stations had passed within a few kilometres of each other on April 13.

At this time Kizim and Solovyov were continuing their exhaustive tests of the Mir structural components and onboard systems.

The first of the two supply craft to have visited Mir at this point, Progress 25, separated from the Mir station on April 20 and was burned up on re-entry into the atmosphere.

Three days later the unmanned freight spaceship, Progress 26, was launched, docking with the space station complex on April 27.

Search, rendezvous, tethering and docking were carried out by onboard automatic equipment of the spaceships. The cargo spacecraft docked with the station on the side of the service compartment.

Progress 26 delivered fuel for the joint propulsion unit, food, water, equipment and apparatus for the Mir station, as well as mail.

James Oberg writes: "A plot of the relative motions of Mir and Salyut 7 shows that Mir was launched far behind Salyut, overtook and passed it in a day or two, raised its orbit which slowed the relative rates, but still 'lapped' Salyut again and passed it about March 8 (for a second time).

"Relative rates were then trimmed further as Mir drifted up to 40 minuites ahead. In late March its orbit was raised higher than Salyut's and it began falling back on Salyut, passing it again on April 13.

"Mir fell about eight minutes behind, then made another burn (again using the Progress engine) to almost precisely match orbital periods."

Opening of Interkosmos. As astronaut Wubbo Ockels looks on, space suited Soviet cosmonaut Aleksandrov kisses Mrs Neelie Smit-Kroes, Dutch Minister of Transport. Right: is Dr Ruud de Clercq, General Director of The Efteling Park.

INTERKOSMOS IN HOLLAND

The largest Soviet space exhibition ever was opened in Holland on April 12, exactly 25 years after the flight of Yuri Gagarin, the world's first cosmonaut. The exhibition, named "Interkosmos", covers an area of 5000 square meters and houses 150 tons of Soviet hardware. To a large extent models displayed are on a 1:1 scale, others are 1:2 or (in the case of a Soyuz-Salyut-Progress working model) 1:3.

Displayed of course are Gagarin's Vostok spacecraft and working model (with smoke and fire) of the launch complex at Baikonur. Manned spaceflight is represented by the Soyuz spacecraft (the descent module with three space suited cosmonauts inside) and a working model of the Salyut orbital complex.

The exhibition is being constantly updated: a large colour picture of the MIR space station has just appeared and new pictures of Halley's comet taken by the Vega craft. Unmanned spaceflight is covered as well, from Sputnik-1 to Vega and information on forthcoming projects (like the Phobos-Mars investigation) is given. One of the most impressive models in the unmanned section is the life-size Luna 24 back-up spacecraft. Also displayed are the Lunokhod moon rover, lots of communication satellites, space suits, space food, medical equipment and small "space gar-

dens", in which tulips and vegetables are being grown at the exhibition itself.

"Interkosmos" was opened by the Dutch minister of Transport, Mrs Neelie Smit-Kopres. Present were Soviet cosmonaut Aleksandr Aleksandrov (who flew 150 days in Salyut-7), Dutch astronaut Wubbo Ockels (STS-61A), academician Oleg Gazenko and Professor Andrei Kapitas. He and BIS Fellow Peter Smolders organised the exhibition in Holland. Smolders was awarded the Yuri Gagarin-medal of the Soviet cosmonautics federation instituted in 1984 on the 50 birthday of -Gagarin. The occasion marked the first time that the medal had been awarded to an individual outside the Soviet Union.

The exhibition is situated at the "Efteling" family park in the town of Kaatsheuvel, near the city of Tilburg in the south of Holland. It will be open until October 19.

Soviet cosmonaut Aleksandr Aleksandrov (right) accompanied by BIS Fellow Peter Smolders (middle) and Professor Dr Andrei Kapitsa, Chairman of the Exhibition Council of the USSR Academy of Sciences.

Future Capabilities of the Soviet Space Programme

Soviet developments of a mini-shuttle, a heavy lift shuttle and of medium and heavy-lift boosters have previously been reported (*Spaceflight* 1984, pages 194-196 and 410-412). Just what role a shuttle and heavy lift booster will play in Soviet space efforts has since been commanding the attention of Western analysts. *David Anderman* examines information from Soviet sources and finds that it offers no evidence of an imminent need for the introduction of any radically new Soviet launch capability.

The US Defense Department claims that the Soviets plan to orbit a Space Shuttle by 1987 as well as a Saturn V class launcher [1]. However, recent Soviet statements and actions seem to refute these predictions.

The present Soyuz-T series is soon to be phased out in favour of a new modification [2]. This new spacecraft will have an increased on-board computer processing capability, as the T-series computer has proven insufficient for the job of rendezvous and docking. One therefore wonders why the Soviets would develop a new version of Soyuz if a Space Shuttle were almost ready for use.

The maximum total weight of MIR with all six docking ports utilised is 110 tons [3]. This orbital mass can be accounted for by five Cosmos 1443-class modules and one improved Soyuz capsule, all launched by existing space boosters. Among the new proposed payloads are (1) a single shuttle-class payload which, as described by the DoD, would have a mass of at least 30 tons and (2) a payload capacity of over 100 tons, which according to the same sources is offered by the heavy lift booster. Neither proposed payload fits with the six docking port/110 ton orbital mass.

The new space station, MIR, will have an operational lifetime extending into the next decade. As the heavy lift booster seems to have no role in the MIR programme, and yet is to be launched within the next two years, one wonders what its function in the Soviet Space programme will be.

The Soviets have also informed the French government that the 1993 Franco-Soviet Vesta asteroid flyby will be propelled by a Proton booster [4]. No mention has been made by the French of the use of a space shuttle or heavy lift booster in connection with this flight or the 1988 visit by a French "Spationaute" to MIR.

Recent launches of the Proton booster have exhibited an upgrade in its payload capacity. There has been speculation that the Soviets have finally developed a liquid hydrogen-fuelled upper stage in connection with these launches. It is unlikely that the Soviets would upgrade the Proton, for the first time in 20 years, on the eve of its replacement by newer space launchers.

Even the 30-year-old standard booster exhibited a greater payload capacity for Soyuz T-14 in 1985, launching three cosmonauts to Salyut 7 while it was in a relatively high orbit. Normally, the Soviets can launch a crew of only two to Salyut in a high orbit, and must lower Salyut's orbit to enable a three man crew to reach it.

Further clouding the matter is the DoD's change of the reported configuration of the heavy lift booster. Past years' reports have been plagued with internal inconsistencies concerning vehicle thrust and payload capacity to LEO. This year's edition is more consistent, but features a radically new version of the heavy-lift booster. The second and third stages have been dropped, as well as two of the six strap-on boosters. The vehicle is now identical to the Shuttle booster, with a payload module replacing the Orbiter. One wonders if this new configuration represents a departure by the Soviets from earlier prototypes, or a clearer understanding by the DoD of the Soviet vehicle.

References

[1] Soviet Military Power-1986, US Government Printing Office.
[2] V.A. Dzhanibekov on Soviet TV 15 March 1986 1800 GMT.
[3] Press Conference at the Gagarin Cosmonaut Training Centre, reported in the Los Angeles Times, April 12, 1986, page 22.
[4] The Soviet Year in Space-1985, Nicholas L. Johnson, Teledyne Brown Engineering, page 63.

Up-rating Proton Booster Performance

M.Q. Hassan, of the Space and Astronomy Research Centre, Baghdad, writes:

The description of the 'Mir' space station with six docking ports and 76 m^2 of solar panels suggests a larger station than Salyut. I doubt very much that all this with its individual crew compartments weighs less than the 25 T limit that can be launched by the known Proton vehicle. Neither do the given figures indicate that it is the anticipated 100 T space station to be launched by the new HLLV that is under development (*Spaceflight* 1984, p.410). It seems likely that the Soviets have uprated the Proton booster using maybe a LOX/LH_2 third stage to bring the LEO payload to over 30 T.

New Insight Into Space Activity

by Dr. H. Pauw

A recent publication entitled "Kosmonavtika", Entsiklopediya, editor V.P. Glushko, Sovyetskaya Entsiklopediya, 1985, contains many new facts about the Soviet Space programme. Dr. H. Pauw has examined the text in detail and presents below for *Spaceflight* a short article together with interesting tabulated information which fills in a number of gaps in the knowledge of Soviet space activities.

In recent years much new information has come to light on various details of the Soviet space programme. V.N. Bychkov [1] and V.P. Glushko [2] have published considerable amounts of data on different types of liquid rocket engines. Furthermore details were revealed by M.V. Keldysh [3], describing the work of S.P. Korolyov. A review of the total Soviet space programme was issued by V.P. Glushko [4]. The latest publication of V.P. Glushko [5] gives more details of the Soviet space programme, and the most important of these are described below.

Proton Launcher

The Proton launcher is a launch vehicle of two, three or four stages that has been in use since 1965. Small high pressure rocket engines with afterburning are installed on all the stages. The propellants in all stages are nitrogentetroxide (N_2O_4) and unsymmetrical dimethylhydrazine (UDMH).

The first stage of the Proton launcher consists of six strap-on boosters with a total thrust of about 9 MN. Each booster contains the RD-253 single chamber liquid rocket engine, which can swivel in one direction for steering.

The second stage contains four single chamber liquid rocket engines with a total thrust of 2.4 MN. An identical single chamber rocket engine with a thrust of 0.6 MN is used in the third stage. Also in the third stage four engines with a thrust of about 30 kN that can swivel for steering are incorporated.

The length of the Proton launcher is 44.3 m without the payload. The maximum diameter is 7.4 m.

The Proton launcher is able to put about 20 T in Earth orbit. The two stage version was used for the three vehicles Proton 1-3, while Proton 4 was the three stage version.

To launch Zond 4-8, Luna 15-24, Venera 9-16, Mars 2-7, Raduga Ekran, Gorizont and satellites of the Cosmos-series, a fourth stage with a thrust of 83 kN was added.

In Ref.5 it is stated that the Salyut space stations were launched by the three stage version.

Block – D

This is an escape stage used to launch space probes from low Earth orbit to escape velocity. It was specially designed for long duration in space with the possibility of multiple starts of the steering engines. The maximum mass including the propellants is 17.3 T, the length is 5.5 m and the maximum diameter is 4 m at the connection with the last stage of the Proton launcher. The propellants are liquid oxygen and kerosene. The

Table 1. Rocket engines developed by GDL-OKB.

	RD-100	RD-101	RD-103	RD-107	RD-108	RD-111	RD-119	RD-214	RD-216	RD-219	RD-253	RD-301
Oxydizer	liq. ox.	liq. ox.	liq. ox.	liq. ox.	liq. ox.	liq. ox.	liq. ox.	mix. of nitr.ox nitr. ac.	mix. of nitr.ox. nitr.ac.	mix. of nitr.ox. nitr. ac.	N_2O_4	liq. fluor
Fuel	75%alc.	92% alc.	92% alc.	kerosene	kerosene	kerosene	UDMH	kerosene	UDMH	UDMH	UDMH	liq. ammonia
Propellant ratio (oxydizer/fuel)				2,47	2,39		1,5	3,97		2,5		2,7
Thrust sea level (kN)	267	367	432	821	745	1407		635	1469		1474	
Thrust vacuum (kN)	307		500	1000	941	1628	105	730	1728	883	1635	98,1
I_{sp} sea level (m/s)	1990		2160	2520	2430	2700		2255	2429		2795	
I_{sp} vacuum (m/s)	2325		2430	3080	3090	3110	3450	2590	2857	2875	3100	3928
Length/Diameter (m)	3,7/1,65		3,12/1,65	2,86/2,58	2,86/1,95	2,34/2,76	2,17/1,02	2,38/1,5	3,49/2,3	2,04/2,2	2,72/1,5	
Mass engine/+ construction (kg)	885/1063		870/1030	1155/1275	1250/1350	1480/1650	168/179	645/755	1325/1515	665/755	1280/1460	
Burningtime (s)	~65		~120	140	320		260	140	~170	125	130	750
Chamber pressure (MPa)	1,59		2,39	5,85	5,1	7,65	7,89	4,36	7,35	7,35	14,7	11,8
Exit pressure (kPa)	88		98	39		59	6,2	69	43	27	61	6
Turbine power (kWatt)	400		1100	3820	3240	8460	566	1880	3270	3570	18740	1265
Turbine revolutions (s^{-1})	65		91	138	130	142	350	133	155	158	231	470
Temperature generator gas (K)	650		780				1030			1100	780	
Temperature chamber (K)				3520								4400
Development period	1947-53	1947-53	1947-53	1954-57	1954-57	1959-62	1958-62	1952-57	1958-60	1958-61	1961-65	mid 70's
Application	R-1	R-2	R-5	first stage Vostok Soyuz launcher	sec stage Vostok Soyuz launcher	first stage launcher	sec stage Kosmos launcher	first stage Kosmos launcher	first stage Kosmos launcher	sec stage launcher	first stage Proton launcher	upper stage launcher

Notes: The DR-216 engine consists of two identical engines. Overall construction is the same as for the RD-219 engine. Burning times are probably rounded off figures.

SOVIET SCENE

	TDU-1	KDU-414	KTDU-5A	KTDU-35 main/back up	KTDU-417	KTDU-425A	KRD-61
Oxydizer	nitric acid	nitric acid	nitric acid	nitric acid	nitric acid	nitric acid	nitric acid
Fuel	amine-based	UDMH	amine-based	UDMH	UDMH	amine-based	UDMH
Thrust (kN)	15,83	1,96	45,5	4,09/4,03	18,92-7,35	18,89-9,86	18,8
I_{sp} (m/s)	2610	2661	2725	2750/2650	3080-3020	3090-2870	3070
Burning time (s)	45	-40	43	500	650	560	-53
Chamber pressure (MPa)	5,59	1,18	6,28	3,92			9,22
Exit pressure (kPa)				3,9			
Development period	1959	60's	early 60's	1962-67	late 60's	early 70's	1968-70
Application	Vostok Voshkod	Molniya Venera Mars 1 Zond 2 Kosmosseries	Luna 4-14	Soyuz Salyut 4	Luna 15-24	Mars 4-7 Venera 9-14	Luna 16 Luna 20 Luna 24

Table 2. Spacecraft rocket engines developed by PKB A.M. Isayev.

Note: There are two variants of the KTDU-35 rocket engine: KTDU-53, without the backup engine, for the Zond 4-7 spacecraft, and KTDU-66, with a total burning time of 1000 s, for Salyut 1.

thurst is 85 kN with a specific impulse, I_{sp} of more than 350 s. The total burning time is more than 600 s.

During the passive part of the flight special steering engines are used, burning N_2O_4 and UDMH. The stage contains all the necessary systems. However, commands and telemetry from the stage are handled via the systems of the space probe.

For connection to the Proton launcher a special skirt is used, containing a conical part at the base and above that a cylindrical part, all of which is jettisoned after separation of the last stage of the Proton launcher. The nose-cone protecting the space probe is connected to the upper cylindric part of the skirt. The cylindric part can be changed depending on the type of payload.

This escape stage was used during the period 1967 to 1976 for launching Cosmos 146, Zond 4, Luna 15-24, and Mars 2. This last statement suggests that there is also another type of escape stage to launch the remaining payloads during the same period and afterwards.

Rocket Engines Developed by GDL-OKB

Many new details concerning the GDL-OKB liquid rocket engines have now been revealed and are shown in Table 1. The figures for the RD-253 engine give thrust and I_{sp} that are lower than previous estimate (6,7). From these figures one can deduce that the mass of the propellants in the strap-on booster for the Proton launcher is about 68.5 T. The total mass of the booster is about 72 T.

The RD-301 rocket engine is the only engine in the world using the bipropellants liquid fluorine and liquid ammonia. This engine has been fully developed and tested for an upper stage of a launch vehicle. From the burning time, thrust and I_{sp} one can calculate that this upper stage contains about 18.7 T of propellants, about the same value as for the Block-D escape stage, described earlier. One can speculate that this upper stage with the RD-301 engine could be an uprated escape stage for the Proton launcher used since the mid 70's.

Spacecraft Engines Developed by OKB A.M. Isayev

In different chapters of Ref.5 the spacecraft rocket engines developed by OKB A.M. Isayev are described in great detail and a summary is given in Table 2.

The Mass of Soviet Spacecraft

P.S. Clark [6] provides information on the mass of Soviet spacecraft based on the figures by V.P. Glushko [4]. However, only some of the masses could be derived at that time. Now, more details can be revealed. A summary of the mission masses is shown in Table 3.

Launch Vehicle for Meteor 2 Satellites

It is stated in Ref. 5 that the Meteor 2 satellites in a 900 km orbit are launched by the Soyuz launch vehicle, instead of the Vostok launch vehicle as previously thought.

References

1. V.N. Bychkov: "Kosmicheskiye zhidkostno-raketnyye dvigateli", Novoye v zhizne, nauke, tekhnike; Seriya "Kosmonavtika, astronomiya"; No. 9, pp 1-64.
2. V.P. Glushko: "Rocket Engines GDL-OKB". Novosti Press Agency Publishing House 1975.
3. M.V. Keldysh: "Tvorcheskue Nasledie Akademika" S.P. Korolyov, Nauka, Moscow, 1980.
4. V.P. Glushko: "Razvitiye Raketostroeniya i Kosmonavtiki v SSSR". Mashinostroyeniye, 1981.
5. V.P.Glushko: "Kosmonavtika" (entsiklopediya) Sovyetskaya Entsiklopedya, Moscow, 1985.
6. P.S. Clark: "Soviet launch vehicles: an overview *JBIS Soviet Astronautics*, Vol 35 February 1982, pp 51-58.
7. A. Bond and J. Parfitt: "The Proton Launcher" *Spaceflight*, Vol 27, July/August 1985, pp 318-320.
8. P.S. Clark: "Soviet spacecraft masses for earth orbital programmes, and for deep space missions *JBIS Soviet Astronautics,* Vol 38 January 1985, pp 19-30.

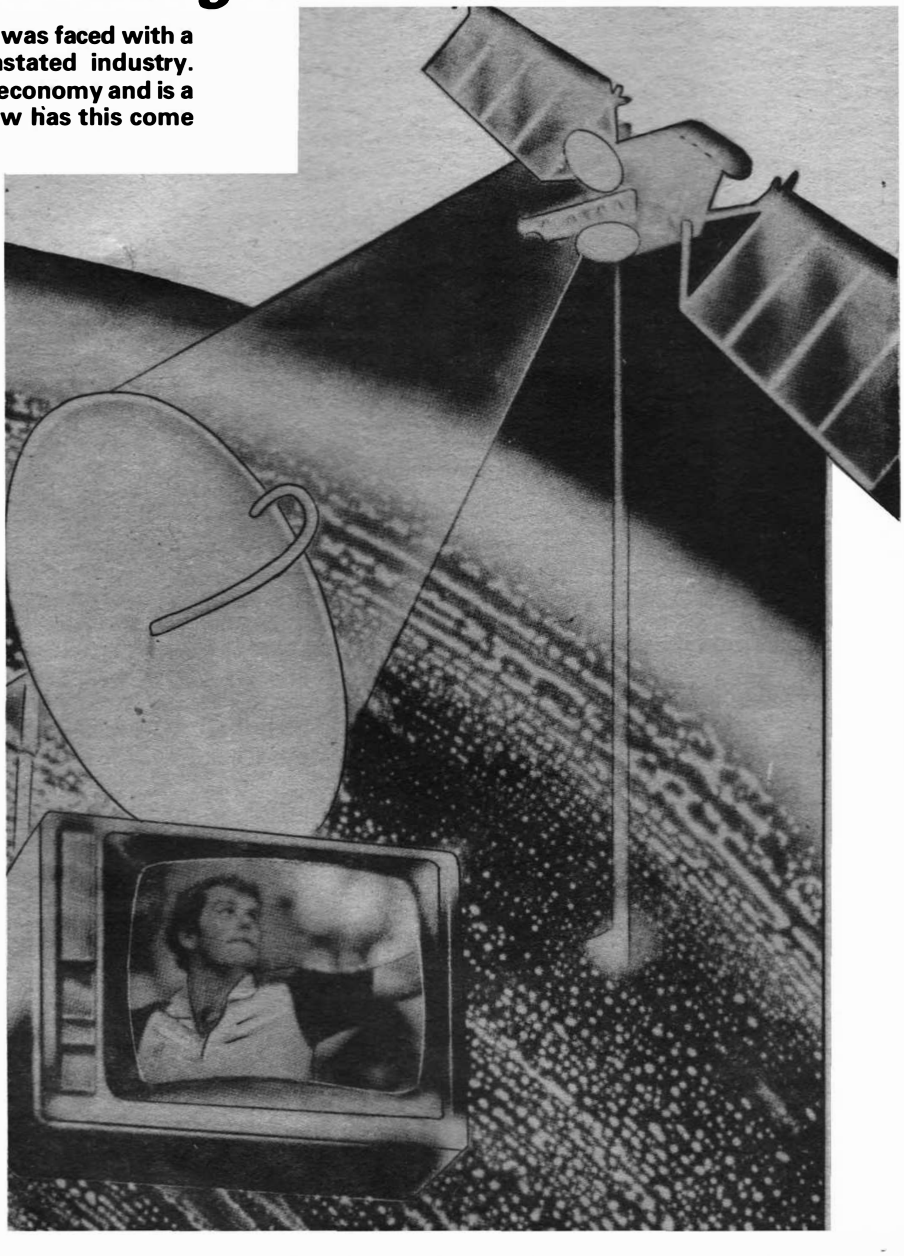
Table 3. Masses of Soviet Spacecraft (kg).

Elektron 1 and 3	350
Elektron 2 and 4	445
Interkosmos	200 - 1300
Venera 11 (lander)	4450 (1600)
Venera 12 (lander)	4461 (1612)
Venera 13 (lander)	4363 (1645)
Venera 14 (lander)	4363,5 (1645)
Venera 15	5250
Venera 16	5300
Luna 12	1620
Luna 13 (lander)	1620 (112)
Luna 15	5700
Luna 16 (lander)	5727 (1880)
Luna 22	5700
Zond 4-8	5200 – 5500

Note In a table of ref. (5) "Spacecraft and rockets launched into deep space for the period 1959-84" the total mass of Venera 11 and 12 was quoted as 9400 kg.

FRANCE

World Leader in High Technology



At the end of World War 2, France was faced with a failing peasant economy and devastated industry. Today France has a wealthy modern economy and is a world leader in high technology. How has this come about?

In the aftermath of the war, France's economic recovery was planned at national level and has since been managed by successive 'Soviet-style' 5-year plans of national regeneration. Committed state sponsorship of national projects has provided the key to success. In 1959, General de Gaulle established the principle that France should have its own independent technology. So began the technological revolution of France, technological success being achieved through the committed application of science and money. France's industrial base expanded with economic success and international marketing – a car industry, a radar industry, a nuclear power industry, an armaments industry, smaller industries (such as the apple-growing industry) and an impressive aerospace industry.

In the 1950's, Britain had the Blue Streak launcher under development, but the opportunity to lead Europe into Space was lost through successive governmental indecisions. France, however, under the leadership of General de Gaulle decided that a presence in Space was essential for a country striving for an advanced technological future. France poured money into Space research and development and began launching satellites in the late 1960's with its own equivalent of Blue Streak, the Diamant. The continued development of this rocket culminated in Ariane, a rocket to rival those in use in the USA. The first Ariane launch was in December 1979 from the newly prepared equatorial launch site in French Guiana.

France's interest in Space has also been commercially motivated. Progress has benefited from the highly interventionist approach of the state which has been the driving force behind the country's high technology on all fronts. A production line financed jointly with other countries through ESA produces one Ariane launcher every nine weeks. The demand for spacecraft launchings by Ariane exceeded the capacity available even before the Shuttle tragedy and the suspension of further Shuttle launchings. Outstanding orders for Ariane launchings provide a $1 billion order book of profitable business.

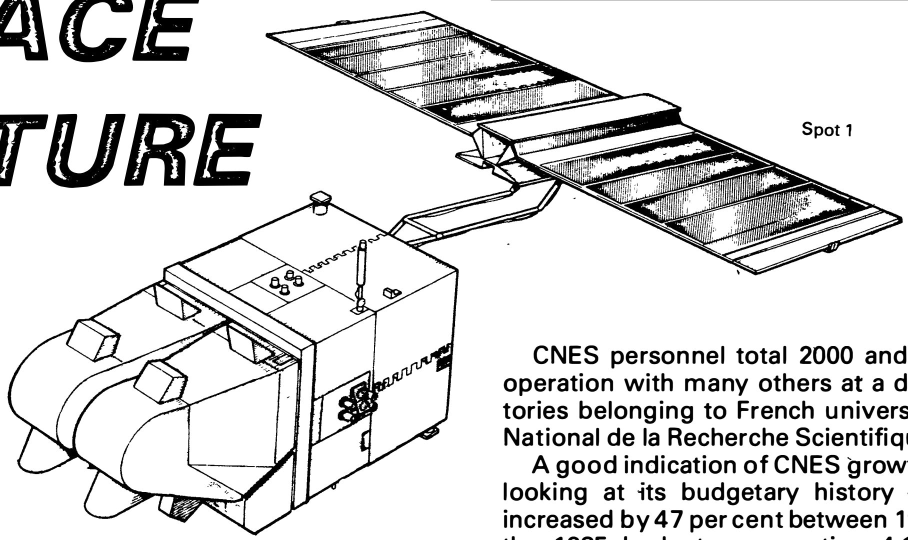
Another commercial venture of France concerns an Earth resources satellite that employs a stereoscopic camera and provides pictures of exceptionally high ground resolution (10m). The first such satellite, Spot 1, was put into orbit by an Ariane 1 launcher on February 22, 1986 (***Spaceflight*** 1986, page 167). A financial return is being sought from the international sale of the high definition pictures for mapping, agricultural survey, town planning and oil exploration etc.

Later this year, France launches a European direct broadcast satellite that will pioneer an extension of TV services beyond national boundaries in Western Europe. This project is a further example of the French government seeing the potential of a new development and quickly deciding to back it.

Commercial ventures are not, however, without their risks. The French approach has been to seek involvement in new space developments as a national commitment, take the risks and re-assess their prospects some time later. This compares with the more conservative British approach which is essentially market-led, the government's role being to encourage companies to modernise and engage in new technologies for which they have or can foresee a market. In France, the political will of General de Gaulle lives on, requiring the technological revolution to continue as a sign of national survival and national prestige. Space is at the sharp end of this movement.

BUILDING A SPACE FUTURE

Early Government sponsorship for an expanding and broad-based space industry has established France at the forefront of international space activities. It is now ranked third in the world league of big space spenders and contributes around half of the total European space budget each year.



Spot 1

The French National Space Agency (CNES)

CNES was created in 1961 following a decision by the French Government to enter the space field and from the beginning was given the role of selling its products either directly or through affiliated companies like Arianespace or Spot Image.

Operating from four centres — Paris (headquarters), Toulouse (technical), Evry (launch vehicles) and Kourou (launch base) — CNES gained experience in space technology through international cooperation as well as pursuing purely national objectives.

The majority of France's national programmes are integral to ESA's. For example, one of the main programmes undertaken by CNES (as overall prime contractor) under ESA auspices was Ariane, a French proposal based upon the experience developed with the purely national Diamant launcher programmes which put the first French satellite into orbit on November 26, 1965.

Working with different French government departments, CNES has developed telecommunications satellites such as Telecom 1A and 1B, TDF 1 and 2, and in the field of Earth observation has developed its own Spot programme. Images from this are soon to be sold throughout the world by Spot Image (a CNES affiliate) to cus-tomers engaged in cartography, geology, agriculture and environmental studies.

In addition, CNES is involved in European cooperative programmes such as ECS (telecommunications), Marecs (maritime communications) and Meteosat (meteorology satellites).

The French national space agency is also working on numerous scientific programmes, either within the framework of ESA, or with bi- or multinational ventures. Examples of these include Hipparcos, Giotto, Exosat, Sigma, Vega, ISPM, ISO and the Space Telescope.

CNES personnel total 2000 and there is close co-operation with many others at a dozen or so laboratories belonging to French universities or the Centre National de la Recherche Scientifique (CNRS).

A good indication of CNES growth can be found by looking at its budgetary history — yearly funding increased by 47 per cent between 1980 and 1984, with the 1985 budget representing 4.137 billion French francs.

The agency will soon reach its first quarter century and future goals, implying continuous growth, have already been fixed. There are Earth observation programmes, advanced space-based telecommunications systems, pure science programmes involving study of the universe, the Ariane 5 heavy launch vehicle, and the manned mini-shuttle Hermes in conjunction with the Columbus Space Station.

Commercial and marketing activities for CNES are handled by a number of subsidiaries.

Arianespace
CNES subsidiary
Promotion and commercialisation
Ariane

Satel Conseil
GIE
Telecommunications consultant

Prospace
GIE
Promotion and space technology
French manufacturers

GDTA
GIE French Aerospace Remote Sensing Group

SPOT Image
Subsidiary
Commercialisation of SPOT imagery

Intespace
Subsidiary
Satellite testing

FRANCE

CNES in 1985

Last year was very important for CNES. Main events were the Vega Venus lander missions, the first flight of a French astronaut aboard a NASA Space Shuttle, and the official go-ahead for the Ariane 5 and Hermes programmes. 1986 has already seen the beginning of commercial Spot operations and this will be followed later in the year by the birth of the direct television TDF 1 system.

Two Vega planetary missions were performed within the framework of Franco-Soviet cooperation. The spacecraft were launched from Baïkonur in mid-December 1984. The first part of their two-fold odyssey was to reach Venus by early June 1985, which they did, when both spacecraft separated in two: cometary probes continued their flight towards a rendezvous with Halley's comet in March 1986, while the Venus landers came down on the planet's surface after releasing two balloons, which were to analyse the Venusian atmosphere during the descent. Each lander made a normal touch-down and both balloons performed as expected, flying some 10,000 km in 46 hrs. Numerous French experiments and pieces of technical equipment were on board the Vega spacecraft: Venus landers carried UV spectrophotometers, aerosol collectors, mass spectrometers, and meteorological analysers.

By the end of June, French astronaut Patrick Baudry flew aboard Space Shuttle mission 51G. Baudry was selected for the first French manned mission flown in June 1982 by Jean-Loup Chrétien aboard Soyuz T 6/ Salyut 7; Baudry was Chrétien's back-up at that time. His flight was onboard the orbiter Discovery, the mission commander being Daniel Brandenstein. The eight day flight launched three communication satellites, including one Arabsat developed in France by Aerospatiale. A fourth scientific payload was to be released and retrieved using the RMS (Remote Manipulator System). Baudry's task was to operate a series of physiological experiments which were similar to those performed by Chrétien during his 1982 mission. Data gathered during 51G was described as excellent, enabling French scientists and researchers to improve their understanding of life sciences related spaceflight characteristics.

CNES now wants to gain more knowledge of manned spaceflight through actual missions and a second group of seven astronauts was recruited in 1985, four of them being payload specialists and three mission specialists/pilots. The science astronauts are: Dr. Claudie Deshays (28), Jean-Jacques Favier (37), Frédéric Patat (27) and Michel Viso (34). The flight engineers/pilots are: Jean-François Clervoy (26), Jean-Pierre Haigneré (37) and Michel Tognini (35).

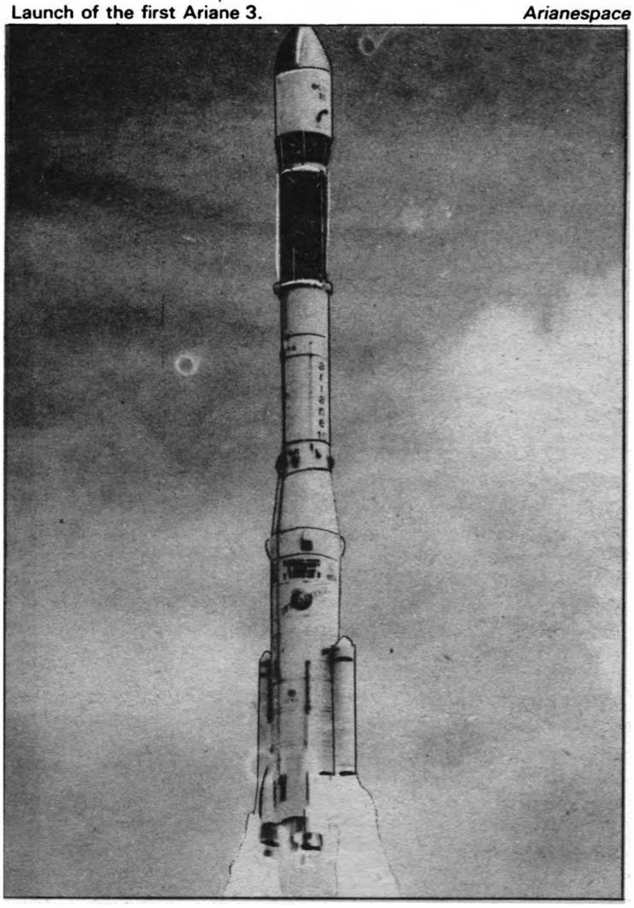
CNES now has a group of nine astronauts who will serve as a basic team, with two main assignments each, to provide French participation in opportunity missions negotiated with either NASA or Intercosmos during the coming years, and to take charge of flight crew responsibilities during the design and testing stages of the Hermes spacecraft.

Plans are currently being finalised for a long

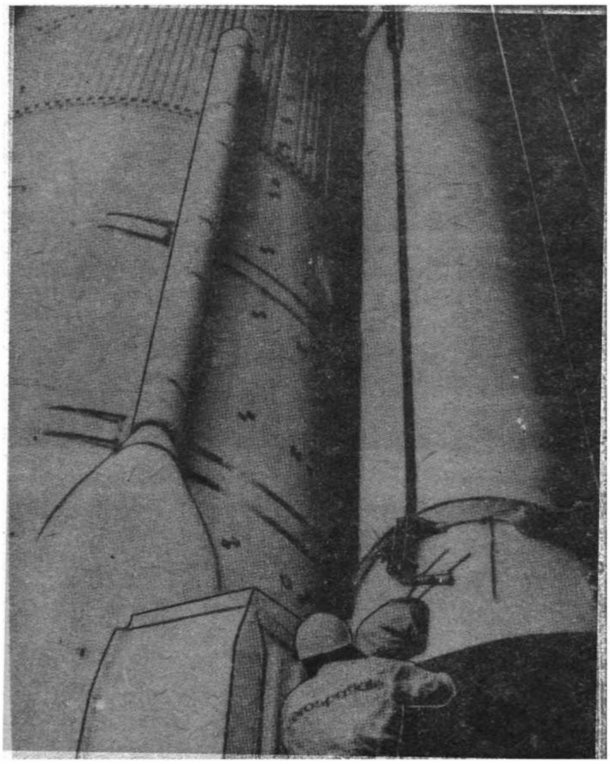
Major programmes with French participation

French national programmes	
Telecom-1	*Three telecommunications satellites for intra-company links links, conventional telephony video communication links, overseas links. 1984*
Spot	*Three remote sensing satellites for inventorying earth resources, 1985-86*
HM-60	*Development of high-thrust cryogenic engine for Ariane-5. 1981.*
Bilateral programmes	
Argos	*French data collection and location system flown on 11 U.S. satellites in operational service. 1978*
Vega	*French experiments on board Soviet probes to study Venus and Halley's Comet. 1984*
TDF-1/2	*Operational direct TV broadcasting system. Two satellites. 1986.*
Involvement in European Space Agency (ESA) programmes	
Ariane	*FAmily of heavy launchers developed under CNES prime contractorship*
ECS	*European telephone and video telecommunications satgellites*
Marecs	*Maritime telecommunications: five satellites. 1982*
Meteosat	*Meteorology and data collection: five satellites. 1981*
Eureca	*Retrievable carrier deployed and retrieved by space shuttle. Two flight units. 1987*
ERS-1	*Oceanographic remote sensing satellite. 1987*
Hipparcos/ Giotto Ulysses	*SCientific satellites for basic research in planetology and astronomy. 1985*

Launch of the first Ariane 3. *Arianespace*



FRANCE



A close-up of the Ariane 3 solid-propellant booster. *Arianespace*

duration flight of a French national on the new Soviet Space Station, Mir, during the next two years.

Aerospatiale, Space and Ballistic Systems Division

Aerospatiale Space and Ballistic Systems Division is the industrial architect of the Ariane launch vehicle and is also one of a limited number of world companies with the capacity to ensure prime contractor responsibilities for communications satellites. Aerospatiale has already participated in the construction of some 35 satellites in orbit. It employs 6000 people and its activities are divided between military programmes 60.7 per cent, launchers 13.9 per cent, satellites 17.0 per cent and miscellaneous 8.4 per cent. It has three centres which are concerned with the following areas of work:

1. Lew Mureaux (near Paris)
   — Design, and technical project management of major aerospace systems,
   — Launch vehicles,
   — Satellite subsystems,
   — Metal structures,
   — Composite material structures.

2. Aquitaine (near Bordeaux)
   — Missile Integration,
   — Wound filament structures,
   — 3-D composite materials and structures.

3. Cannes (French Riviera)
   — Satellite design, integration, testing,
   — Equipment bay integration,
   — Satellite subsystems,
   — Optical systems.

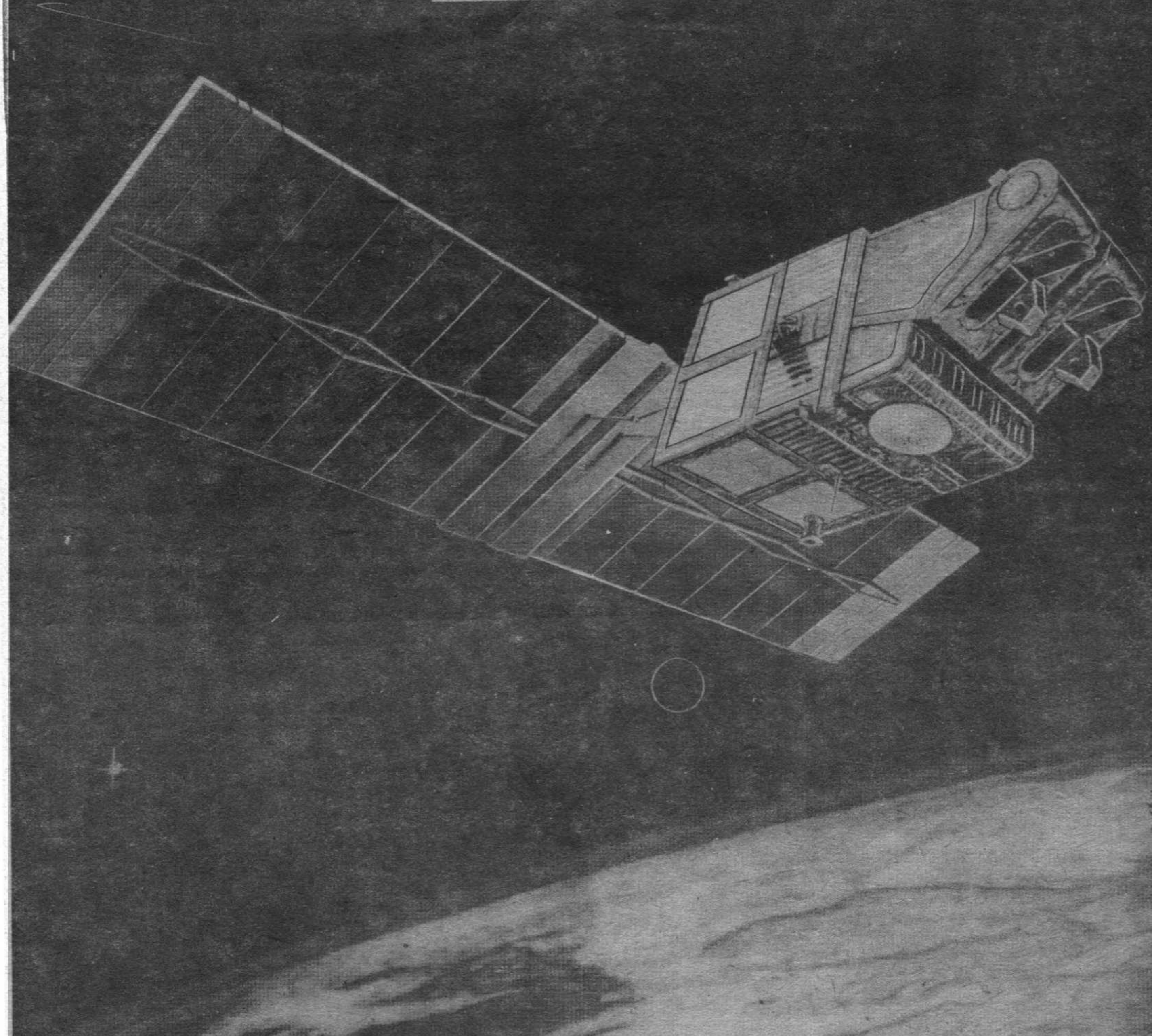
Important space events in which Aerospatiale has been involved are:

1981	
June 19	Ariane L-03 launches Meteosat II and India's satellite Apple.
July 28	Meteosat II transmits its first images of the Earth.
Sept	Intelsat orders three additional flight models of Intelsat V bringing the total series order up to 15.
Dec 15	Intelsat V No. 3 launched.
Dec 20	Ariane L-04 launches Marecs A. With the success of this fourth test flight, Ariane is declared operational.
1982	
March 4	Launch of Intelsat V No. 4.
July 13	Aerospatiale selected by ESA for the study of Europe's future launch systems (reusable and man-rated)
July 14 & 16	Signature of the contract for the Franco-German Direct TV Broadcasting satellites TDF-1 and TV-SAT.
Sept 28	Intelsat V No. 5 launched.
Nov 3	Aerospatiale and Eurosatellite are selected by Swedish Space Corporation as prime contracctors for Tele-X the direct broadcasting satellite and data transmission satellite for Sweden, Norway,and Finland.
1983	
May 19	Launch of Intelsat V FU6.
May 26	Launch of Exosat (Thor Delta).
June 16	Launch of Ariane L6/Sylda (ECS-Amsat).
Oct 18	Launch of Ariane L7 (Intelsat V FU7).
1984	
March 4	Launch of Intelsat V F-8 by Ariane V8.
May 15	Signature of the contract for three operational Meteosats.
May 22	Launch of Ariane V-9 (Spacenet 1).
Aug 4	Ariane V-10 (the first model of Ariane 3) successfully launches Telecom 1 and ECS 2.
Sept 11	Ariane 3 (V-11) launches Spacenet and Marecs B-2.
1985	
Feb 8	Arabsat 1-A and Brazilsat launched by Ariane 3 (V-12)
May 7	Launch of Ariane 3 (V-13) with G-Star and Telecom 1-B.
June 17	Launch of Arabsat 1-B by the Space Shuttle Discovery.
June 29	Launch of Intelsat V-A F-11 by an Atlas Centaur.
July 2	Giotto launched by Ariane V-14.
Sept 12	Ariane 3 V-15 launched (failure).
1986	
Feb 22	Spot 1 and Viking (Sweden) launches by an Ariane 1 (V-16).

EYES IN THE SKY

– The French SPOT programme

The combination of satellite-based remote sensing as a means of image acquisition and the latest techniques in image interpretation promises to yield a wealth of information with many applications, including improved management of the Earth's natural resources.



FRANCE

It is now eight years since the French Government gave the go-ahead for the Spot civil Earth observation programme, conceived by the country's national space agency, CNES.

The programme, undertaken jointly with Sweden and Belgium, comprises of both orbiting spacecraft and an extensive ground segment for image reception and processing. These technical facilities are complemented by a marketing organisation, Spot Image, which is responsible for the promotion and sale of Spot satellite imagery.

Delays in the Ariane launch schedule due to the failure and loss of two satellites during launch last September postponed launch of the Spot-1 satellite from the end of 1985 to the early part of this year.

However, on February, 22 after a perfect launch from the Kourou Space Centre in French Guiana the modular design satellite was placed into an 822 km high orbit.

Following separation from the launcher a series of automatic operations took place to configure the spacecraft. These involved the arming of pyrotechnic channels, deployment of arm (supporting folded solar panels), roll and pitch (Earth) acquistion, unfolding of solar panels and the rotation of the panels.

The second satellite in the series, Spot-2, is in production and last June two further spacecraft, Spot-3 and Spot-4, were ordered to ensure continuity of service after 1990.

Spot data is intended for use in a wide variety of situations which include:

- Map-making.
- Forestry.
- Town-planning and land development.
- Geology, mineral and oil prospecting.
- Agriculture and land utilisation.
- Coast-line surveys.

The Spot-1 payload comprises two identical HRV (High Resolution Visible) imaging instruments, two image data recorders and an image telemetry package for data transmission to the ground.

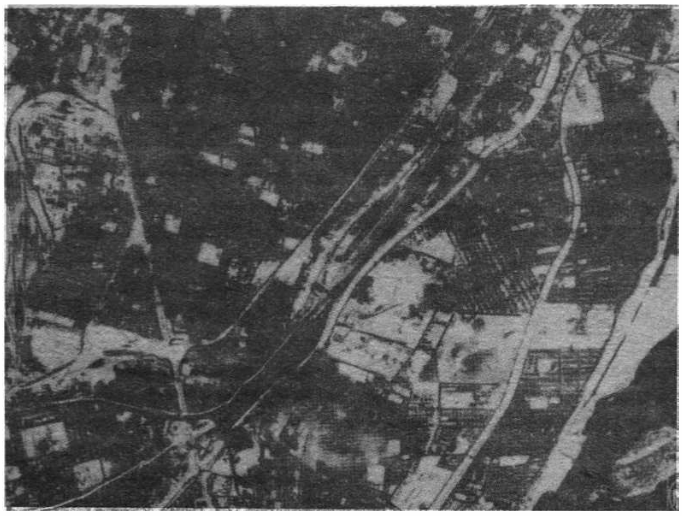
To meet requirements expressed by potential users the imaging instruments can produce high resolution (10 m and 20 m) pictures in panchromatic or multispectral modes.

As well as high geometric quality, the HRV's can produce images with clear radiometric characteristics (quantity of light returned by a surface over a given range of wavelengths) which is of special interest to applications involving vegetation, as they can be used to identify plant species and determine their state of health.

The Spot system also offers revisit potential, thanks to an oblique viewing capability, permitting frequent observation of any point on the Earth's surface, and the capability of acquiring images of a given area using different viewing angles, resulting in stereo pairs.

Most of the data collected by Spot-1 will be downlinked to the two main receiving stations at Issus-Aussaguel near Toulouse and Kiruna in northern Sweden, and then transferred to the Space Imagery Rectification Centres (CRIS) at the CNES Toulouse Space Centre and the Satimage facility in northern Sweden.

Work is also currently in hand on setting up Spot direct receiving stations in Canada, Bangladesh, Brazil, India, China and Pakistan.



Extract of the panchromatic image at 1:50,000 scale, showing part of Montreal, Canada.

The Spot-1 orbit, at an altitude of 822 km, is synchronous with the rotation of the Sun and Earth to ensure constant illumination of areas under observation. Every 26 days, after 369 revolutions around the Earth, the satellite crosses over the same point on the globe.

Acquisition of high resolution imagery from an altitude of over 800 km demands very high precision attitude and orbit control, and the Spot subsystem features three modes of operation:

1. A high-precision pointing mode with various sensors, the onboard computer and momentum wheels as active components.

2. A coarse pointing mode using hydrazine thrusters for attitude correction.

3. A safe-hold pointing mode which is only activated in the event of an onboard computer hardware or software failure.

The Spot onboard data handling (OBDH) system is responsible for performing a number of innovative functions due to the fact that contact with any one ground station is limited to a few passes per day (five to six at the latitude of Toulouse), each lasting no more than 10 minutes.

These involve the satellite being able to execute time-lag commands and image acquisition without ground controller intervention, and, in the event of failure, possessing the capability to instantly recognise the occurence of a fault and check its propogation.

Launch of Spot-1 marks the beginning of a new phase in commercial space operations inspired by the desire to set up a truly operational satellite-based Earth observation system.

While the French Government and CNES are the clearly defined operators of the Spot satellite, responsible both for its proper operation and follow-on programmes, the Spot Image company is in charge of product marketing and distribution.

FRANCE

Broadcasting from Space

The application of Direct Broadcasting Satellites has made a slow start but France, among the first in Europe to develop a DBS system, is poised to make the most of this new commercial opportunity.

The launch of a direct broadcasting satellite, TDF-1, by Ariane in the latter half of 1986 will be the climax of 11 years research and development.

Back in 1975, the far-sighted French Government awarded contracts to various French industrial firms to research and develop the technology that would be needed for the design and construction of a DBS system.

These contracts concerned high-power travelling wave tubes (TWTs), multi-source Ku-band antennas, and deployable high-power solar arrays.

CNES and TDF (Télédiffusion de France) also initiated a joint study to define the possible general characteristics of a DBS system to service France.

In 1978 the similarity of the objectives of their respective DBS programmes and the advantages of bilateral cooperation led France and the Federal Republic of Germany to envisage a binational effort. At the French-German summit of October 1979, the decision was taken to proceed with the development, production and launching of two DBS satellites of virtually identical design: one for France and one for Germany. The joint project was outlined in an agreement signed by the two governments in April 1980.

This agreement called for the joint development, building, launching, positioning and experimental operation of the two satellites to be known at TDF-1 and TV-Sat. The two organisations responsible for the operation of these spacecraft are TDF and Deutsche Bundespost.

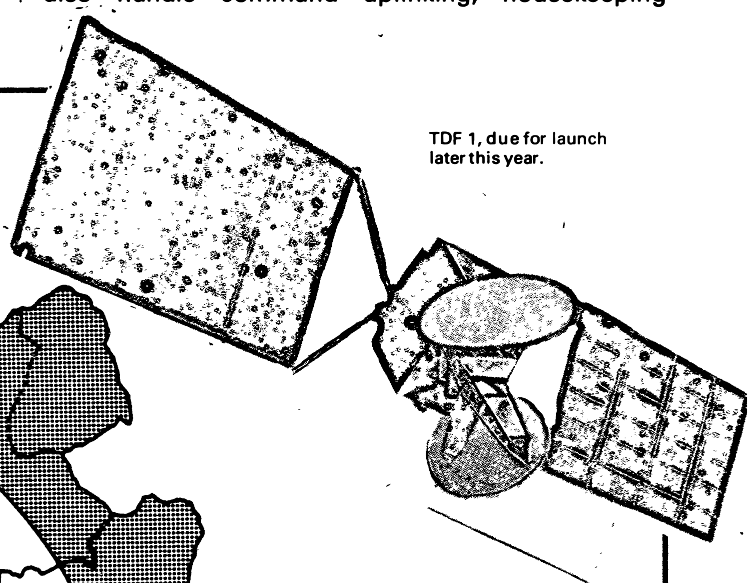
Overall project management is entrusted to a French-German Steering Committee composed of persons with national-level responsibilities for space questions (senior officials of CNES and the FRG Federal Ministry for Research and Technology) and representatives of the operating organisations (TDF and DB).

Day-to-day project management is the responsibility of a joint project team set up in September 1980 and located at Munich. This team comprises representatives of all four organisations involved in the project.

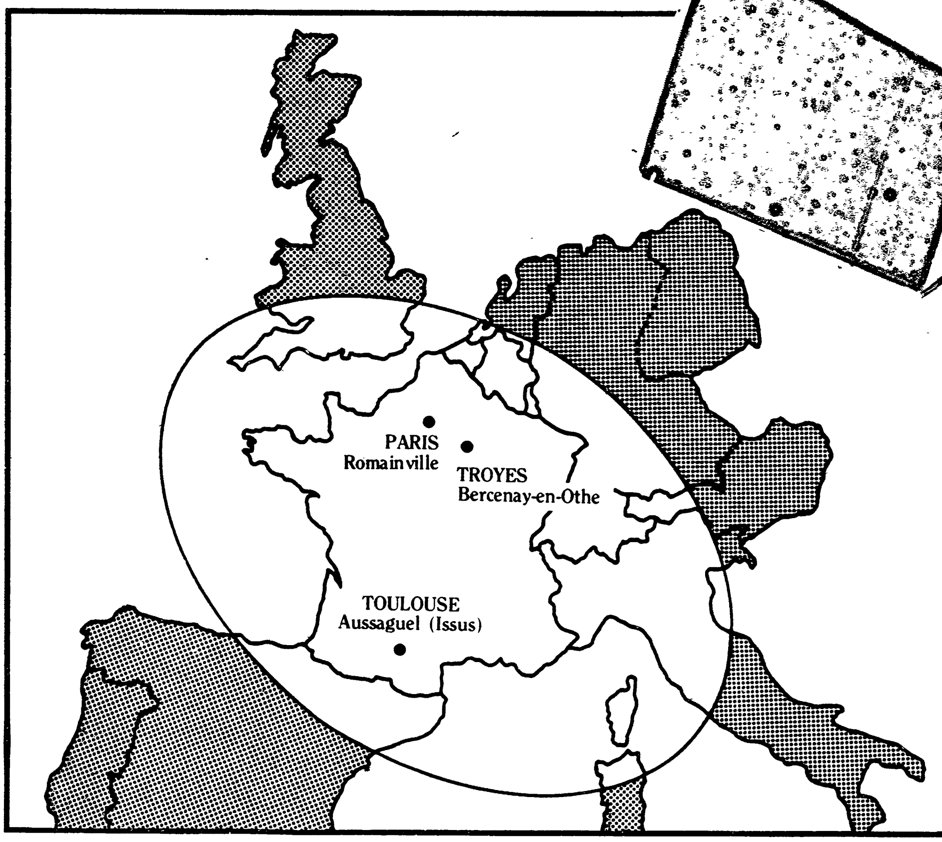
TDF-1, capable of simultaneous broadcasting on five channels, has been designed for launching by Ariane-2, currently scheduled for November 1986.

The payload consists of five transmitters and six power amplifiers, but to keep the solar array within reasonable proportions it has, however, been decided to broadcast simultaneously on only four of the five channels.

The ground station for uplinking programming to the satellite will use an 8 m diametre antenna and 1-kW amplifiers operating on 18 GHz. This station, located at Bercenay-en-Othe near Troyes in eastern France, will also handle command uplinking, housekeeping



TDF 1, due for launch later this year.



The 'footprint' or coverage area for the TDF 1 satellite. The area shown shows the limit for home reception using a small diameter dish.

MINI-SHUTTLE

Hermes, the French proposal for a manned mini-shuttle, would be designed as a service vehicle for space stations, transporting both crew and cargo.

The craft would be launched atop the Ariane 5 heavy-lift vehicle which is being developed by ESA. The current design is based around a configuration known as Ariane 5P which has a large central body with two side-mounted strap-on boosters.

Typical missions for Hermes, the estimated development cost of which is £1,050 million, would include the assembly of space structures and scientific and applications experiments, as well as in-orbit repairs, maintenance and refurbishment of satellites.

The picture shows an artist's impression of the Hermes mini-shuttle in operation above the Earth.

telemetry reception, and tracking (ranging and angle tracking).

The TDF Control Centre, located at the CNES Toulouse Space Centre, is responsible for satellite management, orbit determination and attitude control. It will also provide backup for the main ground station at Bercenay if necessary.

An operational DBS system calls for two satellites in orbit at the same time. Also, the simultaneous management of two satellites will greatly improve channel use flexibility. The combined capacity of the two payloads should make it possible to move rapidly towards the opening of at least four fully operational broadcasting channels.

The decision to go ahead with the second satellite, TDF-2 was taken early in 1985. TDF-2, which will be identical in configuration to TDF-1, is scheduled to be launched in February 1988.

Like TDF-1 and TV-Sat, TDF-2 will be built by the Eurosatellite Consortium.

Last March, the French Government announced the setting up of a new company known as Société d'exploitaiton des satellites. The Government, represented by the Ministry of Finance, CNES, TDF and DGT (a division of the French PTT Administration), holds one-third of the shares.

The industrial challenges associated with the TDF programme are not to be neglected: the potential European market for consumer receiving equipment is estimated at 20 million units or about FF 100 billion (1984 prices).

The TV programming broadcast by TDF-1 and 2 (on 12.5 GHz) will offer sufficient power for reception by 50 cm diameter dishes throughout France and the overspill zone and by dishes 70 to 90 cm in diameter throughout much of the rest of Europe.

The new technical standards for DBS TV broadcasting, known as "D2-MAC Packet", have been adopted by both France and Germany as a replacement for the current standards (Secam and Pal respectively), because of its compatibility with cable networks and its reasonable cost.

This new standard should result in a significant improvement in picture quality while at the same time being compatible with evolution toward high-definition TV and the addition of several (digital modulation) sound channels,

BIOLOGY IN SPACE

Biorack, which flew on the Spacelap D1 flight in October 1985, was designed and developed by French company MATRA. It included scientific equipment (incubators, manipulators, centrifuges, coolers and freezers) for the study of the development and growth of plants and biological samples in zero-gravity.

MATRA, one of the top space electronics firms in the world, has also been responsible for the highly successful Command and Data Management Subsystem (CDMS) during Spacelab flights.

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

INVESTORS TURN TO CHINESE

Chinese rockets could be used to launch the American-built communications satellites, Palapa B and Westar 6.

A memorandum of understanding has been signed between the Chinese national space authority and the Universal Satellite Corporation of New York, which has been negotiating to buy the satellites.

Although there is still a long way to go before a formal agreement to launch the satellites is reached talks are continuing on the possibility of a launch as early as 1987.

If the plan comes to fruition it would be a major coup for the Chinese, who are already working with the Swedish Space Corporation on the possibility of launching the country's Mailstar satellites (***Spaceflight*** April 1986, p.164).

Mailstar, a small satellite being evaluated for electronic mail service, would be launched piggyback with a Chinese Earth observation spacecraft. Earlier this year a 12 month launch reservation agreement was signed between the two parties.

Henry Schwartz, president and chief executive of the Universal Satellite Corp. has been negotiating with Lloyds of London for purchase of the satellites in a deal reputed to be worth around $50 million.

Lloyds and other insurance underwriters had paid Western Union $105 million for its Westar 6 satellite and $75 million to the Indonesian government for Palapa B2. The satellites cost $35 million each when they were new.

Spacewalkers Joe Allen and Dale Gardner manually placed the two satellites in the Shuttle Discovery cargo bay after an intricate space chase in November 1984. They had been considered a total loss a year earlier when their attached rocket stages malfunctioned in separate launch attempts and left the satellites in useless orbits.

They were returned to their manufacturer, Hughes Aircraft, for refurbishment, but for more than a year no buyers could be found. The insurance companies paid $5 million for the retrieval and $5.5 million for refurbishing the satellites.

Henry Schwartz, president and chief executive officer of Universal Satellite Corp. of New York, said one of the satellites is tentatively scheduled for launch from the Space Shuttle in November 1987.

Schwartz still considers re-launch by the American Space Shuttle a possibility, but with delays now amounting to another 18 months before even the first mission is cleared for take-off, the Chinese have a strong card to play.

COLUMBUS HARDWARE

ESA's Columbus Programme Board has reconfirmed that the hardware elements proposed for cooperation with NASA in the International Space Station will be a pressurised module, polar platform and co-orbiting platform.

The Board reviewed the results of detailed definition studies (Phase B1) at a meeting in mid-April and recommended the detailed Phase B2 studies should consist of:

- A pressurised laboratory module for permanent attachment to the International Space Station. This laboratory will be primarily used for materials science, life science and fluid physics research.
- A man-tended free flyer, consisting of a smaller laboratory and a resource module to be launched together on a single Ariane 5.
- An unmanned polar platform primarily for Earth observations applications considering in particular the objectives and requirements of the ESA Earth Observation Programme. The platform will be designed for launch by Ariane 5.

In addition, a further option, consisting of the development of a small co-orbiting platform based on an enhanced version of the Eureca platform currently under development, will also be studied.

MARS OBSERVER

NASA has announced selection of 33 possible investigations for the Mars Observer mission, scheduled for launch in 1990, which will place an unmanned US spacecraft in orbit to conduct a two year study.

During the next six months (instrument accommodation phase) each proposed investigation will be evaluated for compatibility with the Mars Observer spacecraft and mission. Final selection then will take place and the investigations will be developed for the mission itself.

The Mars Observer (***Spaceflight*** May 1986, p207) mission, first in a new series of planetary observers to the inner Solar System, will carry seven or eight instruments. Power for the spacecraft will be supplied by solar panels.

Carried into low-Earth orbit by the Space Shuttle, the spacecraft will be placed into a near-polar orbit of 224 miles. The sun-synchronous, 117-minute orbit will allow instruments to make a complete global survey of the planet's surface and atmosphere about every 56 days. During the two year study the spacecraft will track the planet's seasons and watch seasonal changes on the Martian surface and in the atmosphere.

Three experiments are expected to provide detailed information about the nature of Martian surface material. They are the gamma ray spectrometer (GRS), the visual infrared mapping spectrometer (VIMS) and the thermal emission spectrometer (TES).

The trio of instruments will determine the chemical and mineral composition of the surface by measuring the gamma rays, visible light and infrared (heat) radiation emitted by the surface. The data will provide information on volatile materials (water ice and carbon

dioxide), lava flows, rock types and surface weathering.

The Martian atmosphere is also a major target for investigations. A pressure modulated infrared radiometer (PMIRR) will detect infrared radiation from the atmosphere to measure its chemical composition, pressure, temperature, water content and the presence of atmospheric dust. Other atmospheric measurements will be carried out by the GRS, VIMS and TES as well.

It is uncertain if the mission will include a camera. NASA has selected an imaging experiment for evaluation on the chance that the limited spacecraft resources and budget will accommodate it.

The camera, if selected, would provide synoptic images of global weather systems important for monitoring global dust storms on Mars. It also would give scientists the highest resolution images ever obtained from orbit of selected surface features.

Next month (July) is the tenth anniversary of the landing on Mars by the US Viking spacecraft.

SPACE MISSIONS AT EDINBURGH

Edinburgh University's Artificial Intelligence Applications Institute has been awarded a two year grant to study Artificial Intelligence and knowledge-based methods of planning and scheduling. Funding is being provided by the UK Alvey Programme and the Science and Engineering Research Council.

The Edinburgh team is under the direction of British Interplanetary Society member Dr. Austin Tate and includes another BIS member Ken Currie. In the mid 1970s they produced an AI planner capable of generating project networks for tasks such as electricity turbine overhaul. This work was used as a basis for the NASA Jet Propulsion Laboratory's DEVISER planner which can generate mission sequencing instructions for Voyager's on-board computers (***Spaceflight*** April 1985, p.165).

Preparatory studies over the last two years have produced a prototype planner called "O-Plan" (Open Planning Architecture) which will be used as a test bed for the new work. A graphical interface to the planner will be provided.

The new research will be applied to several different areas. One involves spacecraft mission sequencing using the DEVISER Voyager information or similar information relating to a European spacecraft. This application will allow comparison between planning work at Edinburgh and at JPL.

Other applications include planning for a software implementation project (using data from Price Waterhouse as used on the Alvey IKBS PLANIT club project in which Edinburgh is also involved); Flexible Manufacturing Systems Control; and Logistics Planning.

NEW EUROPEAN SATELLITES

A decision on whether to use Ariane or the Space Shuttle for launch of new generation European communications satellites is due to be made this month (June).

The first of the Eutelsat II satellites is scheduled for launch to geostationary orbit in 1989 and will serve Europe with television, telephone and business data links.

Under a contract for three satellites, with an option on five more, Aerospatiale of France leads a consortium in which UK firm Marconi Space Systems plays a major role.

Marconi will provide the communications system for the satellites in a contract which is worth £75m to the company.

Eutelsat, the European Telecommunications Satellite Organisation was set up to provide telecommunications services by satellite to 26 European countries and 400 million people.

Artist's impression of the new Eutelsat satellite, the first of which is due for launch in 1989. Marconi of the UK is to supply the communications system for an initial three satellites.

SATELLITE DIGEST – 193

Robert D. Christy

Continued from the May 1986 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

SOYUZ-T 15, 1986-22A, 16643.

Launched: 1233*, 13 Mar 1986 from Tyuratam by A-2
Spacecraft data: Near-spherical orbital compartment carrying a rendezvous radar tower, conical re-entry module and cylindrical instrument unit with a pair of solar panels containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried crew of Leonid Kizim and Vladimir Solovyev on a mission to bring into service the new Soviet space laboratory, Mir (1986-17A). Soyuz-T 15 docked with Mir's forward unit at 1338 on 15 March.
Orbit: Initially 193 x 238 km, 88.75 min, 51.62 deg, then by way of a transfer orbit of 241 x 292 km, 89.79 min, 51.63 deg to a docking with Mir in an orbit of 332 x 339 km, 91,19 min, 51.63 deg.

PROGRESS 25, 1986-23A, 16645

Launched: 1008*, 19 Mar 1986 from Tyuratam by A-2
Spacecraft data: Near-spherical supplies compartment carrying a rendezvous radar tower, covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carrying consumables including food, water and fuel to the resident crew aboard the Mir space laboratory. Progress 25 docked with Mir's rear port at 1116 on 21 Mar.
Orbit: Initially 183 x 249 km, 88.77 min, 51.64 deg, then by way of a transfer orbit of 227 x 295 km, 89.66 min, 51.65 deg to a docking with Mir in an orbit of 332 x 339 km, 91.19 min, 51.63 deg.

COSMOS 1736, 1986-24A, 16647

Launched: 1004, 21 Mar 1986 from Tyuratam by F-1.
Spacecraft data: Not available but probably cylindrical with a mass around 5000 kg. Power is provided by a nuclear reactor.
Mission: Radar reconnaissance over ocean areas.
Orbit: 251 x 264 km, 89.67 min, 65.00 deg, maintained by a low thrust motor during the operational lifetime.

COSMOS 1737, 1986-25A, 16648.

Launched: 1922, 25 Mar 1986 from Tyuratam, possibly by F-vehicle.
Spacecraft data: Not available.
Mission: Not known, put probably military.
Orbit: 416 x 430 km, 93.07 min, 73.37 deg, manoeuvrable.

GSTAR 2, 1986-26A, 16649

Launched: 2330*, 28 Mar 1986 from Kourou by Ariane 3 (V-17),
Spacecraft data: Three axis stabilised, box shaped body, approx 1.5 m on each side with a 12 m span solar array. The mass at launch was 1243 kg, reducing to around 700 kg on depletion of fuel.
Mission: US commercial communications satellite.
Orbit: Geosynchronous above 105 deg west longitude.

BRASILSAT 2, 1986-26B, 16650.

Launched: 2330*, 28 Mar 1986 from Kourou by Ariane 3 (V-17).
Spacecraft data: Cylindrical, spin stabilised vehicle with a de-spun aerial array at one end. Diameter is 2.16 m, length 2.95 m at launch, extending to 7.05 m in orbit. The launch mass was 1195 kg, reducing to about 700 kg after apogee kick motor firing.
Mission: Brazilian national communications satellite with transponders operating at C-band (6/4 GHz).
Orbit: Geosynchronous above 70 deg west longitude.

Remote Sensing Data System

Satellite pictures can be enormously useful provided the right picture reaches the right place at the right time. To achieve this, an extensive computer and communications infrastructure is required to cope with the very large amount of data in each picture and the diversity of the user community.

The size of the task is expected to increase rapidly as more accurate and sophisticated sensors are placed in orbit, generating more and more data of interest to an ever wider community of users.

Logica has recently completed a contract for the UK Department of Trade and Industry to define a UK network for the dissemination of remote sensing data. This is a first step towards fulfilling a recommendation of the House of Lords Select Committee on remote sensing and digital mapping.

The data transmitted over the network will originate from a wide range of sources including meteorological satellites, the current Landsat system for observation of Earth resources and the future ERS-1 satellite programme, planned for launch in 1989, which will focus on oceanographic applications.

Ultimately the network will provide communications facilities to distribute data between the various acquisition, archive and processing sites managed by the Royal Aircraft Establishment, Farnborough.

Logica's major objective was to provide a coherent system architecture which will meet the requirements of a phased programme of development for the expected build up of remotely sensed data traffic over the next 10 to 15 years.

The project combined an assessment of the types and quantities of data to be transmitted between sites in the network with consideration of various telecommunications options.

A two-tier network was eventually recommended: a service based on the national packet switched network (in association with its gateways to other networks) to provide the widest distribution of catalogue data and images of a limited size, complemented by a satellite system to distribute the larger images of a high resolution. It was also recommended that the packet switched part of the network should be implemented first.

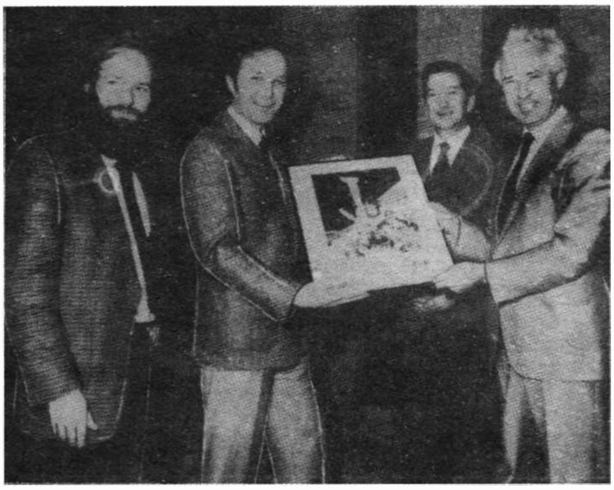
Logica has now commenced the first stage of the implementation, and trials of the terrestrially based service are expected to take place in the latter part of 1986.

INTERNATIONAL SPACE REPORT

HIGH ACCURACY

The stabilisation system controlling the pointing accuracy of the scientific instruments on board the European Space Agency's Spacelab 2 was so sensitive it could even detect disturbances caused by the movement of personnel within the Shuttle Orbiter. At the heart of the system was a Ferranti gyro package and the company has received special thanks from Dornier System GmbH and the ESA for its contribution to the success of the Spacelab 2 mission.

The compliment came in the form of official certificates acknowledging outstanding performance and team achievement which were presented to the company's Space Systems Group at Silverknowes, Edinburgh.



Pictured above (from left) are: Guenter Schmidt and Mario Welsch of Dornier System GmbH with Jim Simpson and Roy Tait of Ferranti Space Group.

Spacelab 2 was the first flight of a precision instrument pointing system (IPS) developed by Dornier System under contract to ESA. It was carried into orbit by the Space Shuttle Challenger last August for what became a highly successful mission dedicated to the study of the Sun.

IPS is a three axes gimbal system providing for acquisition and fine pointing of ultra violet telescopes and spectrographs It incorporates the Ferranti gyro package which has been designed to sense movement and provide attitude data to the pointing control electronics every 10 milli-seconds. In operation the IPS achieved a pointing accuracy of better than one arc second, enabling all mission objectives to be accomplished.

UK EQUIPMENT ON ARIANE

Ferranti of the UK has received orders for a further 14 sets of inertial measuring equipment for the Ariane satellite launcher.

Worth nearly five million pounds, it brings the total number of systems ordered to 44 and will allow current production levels to be maintained to the end of 1990.

Ferranti's inertial measuring system forms a vital part of the European launcher's guidance and control system, ensuring payloads achieve the correct orbit.

CORRESPONDENCE

Hotol versus Hermes

Neither Hotol nor Hermes Needed

Sir, Hotol uses a superduper secret propulsion system. We know only a few details. The Hotol garb in April's ***Spaceflight*** is about as deep as a Coke ad. That Hotol should achieve launch costs of 20 per cent of today's is just a goal, a promise, a claim of the inventors and is not backed up in any way.

The horizontal launch is quite cost neutral. The launch mass is certainly reduced compared to a rocket, but it is the dry mass that counts, and here Hotol is not much different from rocketry as LOX and LOX tankage are cheap whereas machinery is expensive. Reusability works the same way as for rockets; being desirable for "sufficiently large programmes", but undesirable for "a few annual flights". Short turnaround time is just a claim; and if true at all, it is also true for single-stage rockets of similar payload integration design.

I recommend strongly against Hotol, but not against fundamental research in this novel field of aero-propulsion. I am very dubious about Hermes. I was rather closely involved in the US Dynasoar project and I doubt that Hermes will be accomplished: the overall performance will not be attained with the present mass budget which is limited by the Ariane 5P. I would prefer to see a versatile recovery capsule developed for the Ariane 5P.

HARRY O. RUPPE
Munich

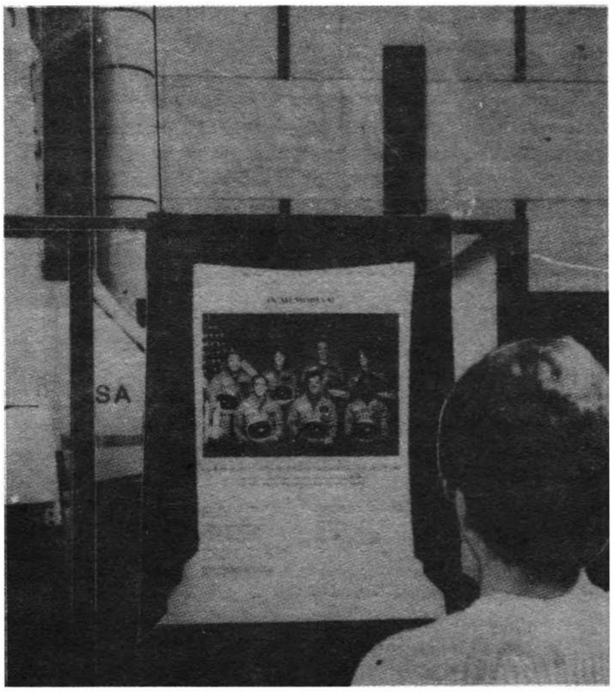
Both Hotol and Hermes Needed

Sir, Jesco von Puttkamer (***Spaceflight*** 1985, pages 348-354 and 395-400.) and J. R. French (***Spaceflight*** 1986, page 183.) both see the need for a heavy lift launch vehicle, and a low cost means of transport to orbit. If both the Hotol and Hermes programmes were to go ahead to plan Ariane 5/Hermes should be operational two to three years before Hotol. Once Hotol is in service and providing low cost to orbit, Ariane 5 should be developed into a heavy lift launch vehicle with two or three HM60's and four solid boosters.

This Ariane 6 would be capable of launching space station components or, with Hermes on top, a European Moon mission. The manned lunar ascent stage would lie upside down in the Hermes payload bay while the disposable descent stage would be housed in a shrouding between Hermes and Ariane. Then Hermes would do a 90 degree manoeuvre in space to join the two stages together. One manned lunar mission per year for a decade would be a proper and affordable goal for Europe. Britain would need to take at least a 25 per cent stake in Hotol so that the French could fund Ariane 6.'

I am sure that the French will never accept Hotol if they think that it will make the Ariane/Hermes redundant.

JOHN A. HARTLEY,
Ripley, Surrey



Museum's Tribute

Sir, I took this picture of the "in memoriam" display set up amid the Space Transportation System-related exhibits at the National Air and Space Museum, while visiting Washington last month.

The "in memoriam" display is mounted in a glass enclosure surrounding a 1/15 scale model of the STS. It is the focus of much attention by museum visitors. Also mounted in the enclosure is a colour picture of President Reagan, showing his reaction to the news that the Challenger had been destroyed in an explosion.

DAVID S. F. PORTREE
Ilinois, USA.

New Missions: Evolutionary Not 'Gung Ho'

Sir, I write in response to J. R. French's letter in the April 1986 issue of ***Spaceflight***. Whilst I agree that the US may have a tendency to opt for the 'high technology' solution to problems, in my opinion it has not been the driving force behind recent US space policy. I would like to comment on the examples of decision-making quoted by Mr. French.

Firstly, the question of upgraded Saturn V versus Space Shuttle. It may be argued that an improved Saturn rocket would compete favourably with the Shuttle, however this would be arguing with the benefit of hindsight which was not available when the decision had to be made. In the early 1970's who would have proposed that America's launch capability up to the next century should be based on Saturn V's and 18's instead of the cheap, reliable space bus the Shuttle should have been.

Today we are faced with a similar decision i.e. continue with the Shuttle or develop a TAV/Hotol type vehicle for transportation into the next century. It would be a brave man who abandoned the TAV/Hotol with all it has to offer.

Secondly, perhaps two docked Skylabs would provide more volume than the proposed Space Station, but when Skylab was available a Space Station was not wanted. Now that a Space Station is wanted, Skylab and the Saturn V's needed to orbit it are simply not available and there is no choice but to start from scratch.

Finally, there is the question of why it would take 15 years to return to the Moon when it only took eight years to get there the first time. This, like the subjects above, is due to politics and changing political emphasis, not to any lack of spirit or vision. With political and public support the US has proved capable of great feats such as Apollo. But when we return to the Moon or set foot on Mars it will be as part of a logical evolutionary process rather that a 'gung ho' leap into the dark as was Apollo. When dealing with human lives is it not right that planning and research come before making headlines? When the history books are written in a thousand years time will the particular decade man first walked on Mars or the number of lives that were lost in the process be more of a measure of our greatness?

PETER R. HALL
Aylesbury, Bucks

CORRESPONDENCE

Likes and Dislikes

Sir, I have just received my March 1986 issue of ***Spaceflight***. What a tacky rag our vanguard journal has become! What an exercise in bad taste the new headlines are. What is the excuse for all this visual noise? In future please show the courtesy of consulting your membership concerning such extravagant format changes. We are, after all, more than a readership, we are a Society.

WOLFRAM LUNSCHER
Saskatoon, Canada

Sir, The coverage given to current Space events in recent issues of ***Spaceflight*** greatly enhances the magazine. A good balance has been struck with the presentation. News items have the right level of impact without overshadowing ***Spaceflight's*** technical content.

P.R. FRESHWATER
Oxon

Sir, The recent addition of colour to ***Spaceflight*** is a very welcome improvement.

PETER R. HALL
Aylesbury, Bucks

Sir, Thank you for the addition of colour artwork to the ***Spaceflight*** magazine. I am grateful for the latest picture of the 'Galileo' probe in the May issue as this excellent colour photograph is not only highly accurate but is of the actual probe rather than the test prototype.

MARK T. PEARCE
Bristol

Sir, I welcome the attempts to jazz up ***Spaceflight's*** appearance, but please do not overdo it!

DAVID TUDOR
Coulsdon, Surrey

Sir, The publication ***Spaceflight*** is consistently improving and remains excellent while the JBIS provides a depth of coverage in a wide range of topics which is unmatched elsewhere. I am also impressed by the speedy and reliable service provided by the Society. Congratuations to all concerned.

DARREN BURNHAM
Oxford

Sir, The magazine looks really excellent, with the addition of colour and the new lay-out. Really high quality.

PETER SMOLDERS
Netersel, The Netherlands

Ed. *Due to limitations on space we reproduce here only a representative selection of readers' comments on **Spaceflight**. So far the 'Likes' have greatly outweighed the 'Dislikes'. We continue to welcome readers' comments.*

Challenger Velocity

Sir, In the feature on the Challenger disaster (***Spaceflight*** 1986, pages 100-102) the PAO announcement at about 75 seconds into the flight refers to a velocity of 2900 feet per second. In fact I believe this velocity to be given with respect to the centre of the Earth as this makes sense when orbital velocities are reached. I calculate the velocity of Challenger at the time of the disaster (72 seconds after lift-off) to be about 1740 feet per second with respect to the launch site. This velocity is composed of a horizontal component of about 1220 feet per second and a vertical component of about 1240 feet per second.

PETE BENTLEY
Northumberland

Membership Promotion

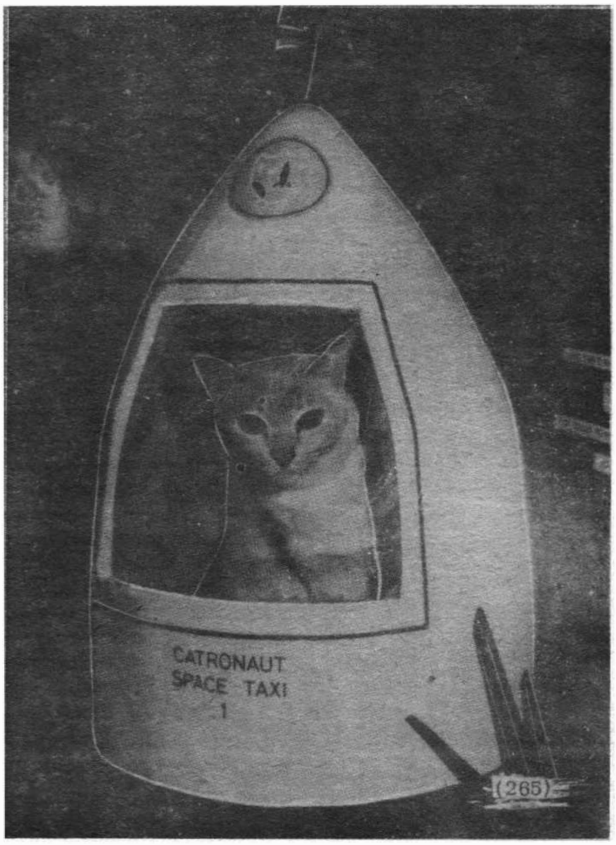
Sir, I read the comments on membership in the May ***Spaceflight*** with interest. I shall photocopy a stack of membership forms and leave them in my waiting room for patients to pick up.

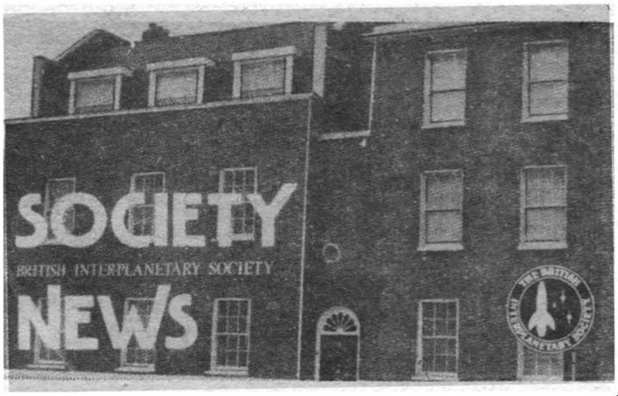
M. J. FOGG
London

Sir, The theme for my pen display at the 1986 Supreme Cat Show will again be Spaceflight. The display will feature Giotto and the comet encounter and will also have a "Catronaut Satellite Orbiter" with "solar panels" on four of its eight sides.

As in previous years I shall display a B.I.S. membership card made out for my champion Burmese female cat which will be complete with paw-print instead of the usual signature. This has always attracted a great deal of attention. Patrick Moore has again kindly sent a card of congratulation to "our Catronaut" and this will be displayed on the pen front curtains. In the last three years Champion Charmeuse Cream Kismet has made her contribution to Astronautics in being exhibited in her Spaceflight theme displays at various cat show venues. She is certainly bringing the name of the B.I.S. to a wider audience!

JOHN W. BURLEY
Devon





SPACE '86
Brighton, 26-28 September 1986

Participants at the Society's SPACE '82 and SPACE '84 weekend gatherings will need no encouragement to be at SPACE '86. These events have provided a unique opportunity for members from all parts of the country and from overseas to meet together for an enjoyable and informative time. A most exciting programme has been planned for SPACE '86, breaking much new ground and providing a breathtaking overview of Space.

The programme first presents the expanding opportunities offered by Space, particularly unmanned probes to the edge of the Solar System with instrumentation that peers beyond into the depths of Space.

The manned aspect takes the form of an up-date on work on Space Platforms i.e. not only the Space Station proposed by the US but the many ancillary Space Platforms for specialised applications which are of considerable interest to Europe.

Programme details appear in this issue of the Meetings Diary and more details can now be given about leading participants. We are fortunate in having Jesse Moore, now Director of Johnson Space Center and responsible for the NASA Space Station with a lifetime of experience on manned Space projects, Dr. D. J.

Shapland, from the ESA Astronaut office and, subject to other commitments, participation by a number of Astronauts. Those who have provisionally accepted invitations to attend are Owen Garriott, Claude Nicollier and the four U.K. Astronauts.

The social aspects of SPACE '86 will include an Opening Reception provided by the Brighton Corporation and a concluding Banquet attended by Guests of Honour. Accompanying persons will have an opportunity for a private tour of the Royal Pavilion and will also find much of interest in the actual proceedings.

Full details of the programme, hotel accommodation and registration forms are available from the Society on request. We meet in the spacious and comfortable facilities of The Brighton Centre, but please book early as seating is limited. We hope to see you there.

RIGHT UP-TO-DATE

Following our main feature in the May issue of ***Spaceflight*** on the report "Pioneering the Space Frontier : Our Next 50 Years" prepared by the United States Commission on Space, UK members may have noted the subsequent inclusion of this item on radio and TV news and in the 'Tomorrows World' programme. The Society is pleased that ***Spaceflight*** is able to fulfill an important role in keeping its readers right up-to-date with new plans and developments for Space.

HALLEY'S COMET ENCOUNTER

A lecture on the recent Giotto encounter with Halley's comet was given to members of the Society by Professor J.A.M. Donnell on April 9.

Giotto marked the first occasion for Europe to venture into Interplanetary Space. A matter of some concern had been a possible early demise of Giotto through imparting debris from the Comet. Drawings by Bessel in 1835 had shown strong ejection activity which did not appear in photographs taken in 1910; but Giotto, in the event, left the matter in no doubt – debris was encountered.

The dust shield was crucial to success, although it was modest in thickness i.e. only 1mm wide at the front and 15mm at the rear. ESTEC had measured its sensitivity beforehand by firing small particles and had been satisfied that the chances of surviving the encounter were good.

The first event was the crossing of a wide diffuse bow-wave, picked up at a distance of a 1,000,000 km from the Comet.

The first picture, transmitted from the probe at 10 pm on March 13, was taken at a distance of 750,000 km from the Comet. This gave a view from 500 km across and suggested a large nucleus 50 km wide.

The first detection of heavy dust was at T minus 70 minutes to encounter though impact remained low until only a few minutes before this took place. At that point, with the spacecraft and the comet approaching each other at a combined speed of 250,000 km per hour, impacts rose to an intense rate, so great that heavy dust impacts at 10 min 58 sec past midnight on March 14, at 1,350 km from the nucleus and two seconds before closest approach caused the spacecraft to wobble wildly with the result that its antenna no longer pointed continuously to Earth. Data

flashed across the screen intermittently. The camera was struck as was the star mapper, though the dust shield itself performed excellently. (NB. It should be possible to calculate later both the mass of individual particles and the total dust mass impacted. The heaviest weight detected was 30 microgrammes).

The last picture to be received before encounter showed a nucleus rather like a large potato, 15 km by 7 km, though its exact shape and size were hard to determine because a part of it was obscured by dust activity. It was clearly irregular and showed several bright spots. Resolution as down to 50 m and showed much jet activity on the sunlit side. The true colour of the nucleus appeared to be jet black. Irregularities on the surface indicated a rotation period of about 52 hours. As Giotto had arrived from the unilluminated side the result of the impact was that pictures of the illuminated side, after encounter, were lost. The nearest distance to the nucleus had been 605 km. Over 3000 pictures were returned.

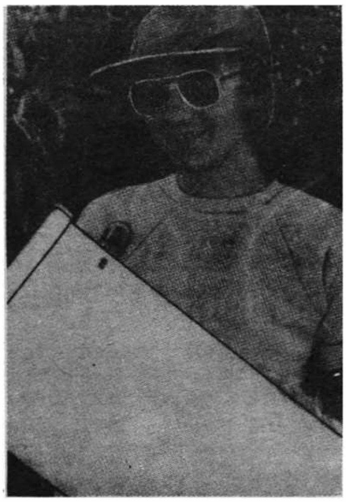
Active control was regained by the Ground Station in Australia 38 minutes later, by which time the spacecraft was as stable as a rock.

Observations of the Comet a few days after encounter showed two areas of brightness, the second of which might have arisen from fragmentation.

Giotto is now on a trajectory which will bring it within 20,000 km of the Earth in July 1990. No decision has been made on future missions but one current proposal is to use it for a further mission, to Comet Grigg-Skjellerup, in 1992.

APPOINTMENT

We are pleased to hear from Michael A.G. Michaud, BIS Fellow, that he will become Director of the Office of Advanced Technology in the US Department of State from this June on moving from the position of Special Assistant for Space Policy in the same office. The office is responsible for the foreign policy aspects of US civil space policy and programmes, and staffs the negotiation of an intergovernmental agreement for European participation with the United States in the international Space Station.



Nathan Kelly, B.Sc.

OBITUARY

It is with deep regret that we record the death of Nathan Kelley (April 1961 – December 1985) who was a Member of the Society.

Nathan died a week after a heart and lung transplant which was performed at Harefield Hospital for congenital heart disease.

His heart defects kept him away from school and much of his learning was self-taught. He developed an early interest in pathology and fish diseases, and at the age of sixteen he discovered two fish cancers which are registered in his name at the Smithsonian Institute in America. He overcame his disabilities to go to Reading University to read Pathobiology, where he attained a B.Sc. Following this, he began a second degree course at University College London, this time in Astronomy which had been a life-long interest.

Ill health forced him to abandon the course in December 1984, since when he spent much of his time in St Ives, Cornwall, where he continued his astronomical studies. He is remembered there for his bravery, his learning and his laugh.

In recognition of his close interest in the Society, his parents have donated his five inch astronomical telescope and collection of books to us.

MEETINGS DIARY

All meetings unless otherwise stated are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ.

7 June 1986, 10 am – 5 pm Forum

THE SOVIET SPACE PROGRAMME

Offers of papers are invited. Members with a special interest in the Soviet space programme are invited to attend. A registration fee of £5.00 is payable. Forms are available from the Executive Secretary on request, enclosing a stamped addressed envelope.

11 June 1986, 7-9 pm Lecture

PROSPECTS OF A MANNED MARS MISSION BY THE YEAR 2010

by J. Daniels, *University of Leicester*

After completion of the Space Station in the mid 1990's one possible goal of the US and its partners is a manned mission to Mars. This lecture will examine the why's, how's and prospects of an actual mission by 2010.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

26-28 September 1986 Conference

SPACE '86 – PROFILES OF THE FUTURE

A weekend conference at the Brighton Centre. The programme will be as follows:

Friday 26 September
Civic Reception and Dance, incl Supper

Saturday 27 September
Opening Ceremony

Expanding Opportunities
European Opportunities in Space (Provisional)
Dr. R. Lust
UK Space Activities in a World Context
R. Gibson

On the Edge of the Universe
The Space Scene
Dr. W. I. McLaughlin
The Outer Solar System (Provisional)
R. O. Laeser
Future Exploration of the Solar System
Dr. G. E. Hunt
A Present View of the Universe
Prof F. G. Smith
Astronomy from Space
Dr. J. L. Culhane
Starlink – Electronic Corridor of the Future
Dr. G. E. Bromage

Space Platforms : A Foothold in Space
Design Drivers for the Columbus Space Programme
P. Truss
European Participation in the Development of the Space Station
Dr. D. J. Shapland
Space Tethers
Dr. I. Bekey
Evening Banquet

Sunday 28 September

Adapting to Space
Europe's Contribution to the New Science of Robotics
Dr. H. Stoewer
Microgravity: Boon or White Elephant?
Dr. G. Seibert
Space Spectacular
H. J. P. Arnold
HOTOL
Dr. R. C. Parkinson
Interstellar Studies at the Crossroads
Dr. G. L. Matloff

LIVING IN SPACE
Presentations by Astronauts followed by an Astronaut Question and Answer Session.

Details from: The Executive Secretary, British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

20 September 1986, 12 noon AGM

41st ANNUAL GENERAL MEETING

The 41st Annual General Meeting of the Society will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on Saturday, September 20, 1986 at 12 noon. Details of the Agenda will be published in due course.

Admission is by ticket available to Corporate members only, who should apply in good time enclosing a stamped addressed envelope.

Council nomination forms are obtainable from the Executive Secretary. These must be completed and returned not later than 12 noon on 27 June 1986.

If the number of nominations exceeds the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all Corporate members.

LIBRARY

The Society Library will be open to members from 5.30 to 7 p.m. on the following dates: **11 June 1986**

RESTORATION DELAYS PRINTING

As reported in the May issue of ***Spaceflight*** (page 224), the Society's copy of Bayer's *Uranometria* has been returned to the book restorers following the discovery of a further concealed page of early obser-vations. We are at present awaiting their report on whether the glued pages can be separated and what new material may be revealed. These developments have inevitably resulted in a delay to the printing of the 500 limited edition fascimile copies originally scheduled for April.

Our apologies for the delay to readers who have already placed orders, but a compensating factor is the prospect of a more interesting final product as both the original pages and the added pages will be reproduced in the fascimiles.

The New Astronomy

N. Henbest and M. Martin, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 240 pp, £9.95, 1986.

While traditional astronomy has been concerned with studying the light from objects in space, the new astronomy described in this test encompasses other types of radiation emitted by celestial objects viz gamma rays, X-rays, UV, infrared and radio waves. The wavelength of light is surprisingly limited. This work covers radiation from extremes of one thousand-millionth shorter to over 100 million times longer than the wavelength of light.

The rapid growth of astronomy probing these wavelength was due, partly, to the discovery of celestrial radio waves in the 1930's. Since then, new types of telescopes have been built to examine other kinds of radiation, besides detectors to record the images in a way that can be comprehended. Much of the sky has been studied in these new wavelengths, even if crudely, with stellar maps prepared to depict various types of radioactive sources, often simply as contour diagrams.

Up to recently one had to rely on optical photographs to illustrate objects emitting in other wavelengths. Now, techniques have been developed which process these images with the result that, in many cases, optical pictures may be the least interesting!

The range studied in this book begins with the Sun and extends outwards throughout the Solar System into the depths of space. Many of the illustrations look very strange, when compared with optical pictures but, nonetheless, represent our new way of looking at the Universe.

Space Stations and Space Platforms – Concepts, Design, Infrastructure and Uses

Eds. I. Bekey and D. Herman, AIAA, 1633 Broadway, New York, NY 10019, USA, 392 pp, 1985, $39.50.

This book focuses on the Space Station and its associated platforms, the central and most visible features in the aim to establish a permanent presence in space. Such a station cannot be operated in isolation, however, it must have transportation for access and for movement to other goals. The assembly of such space facilities and transportation elements will provide the capability not only to service the Earth but to go beyond and establish bases on the Moon and planets.

The present volume denotes relatively few pages to the history and development of the concept of the Space Station before getting straight into its stride with detailed appraisals of Skylab and Salyut. At this point consideration is given to the development of astronomical tools in relation to the Space Station, together with the polar platform for remote sensing which is to co-orbit the Space Station but not, essentially, to be part of it. It is not until the development of satellite communications and the potential for materials processing in space have been dealt with that a contribution appears which details pre-war concepts though these are soon far outweighed by the plethora of designs which emerged through the 1960's and 1970's.

The book continues with a description of potential designs of space stations and platforms, in summary form, ending with a view of possible future space scenarios.

The INTELSAT Global Satellite System

Ed. J. R. Alper and J. N. Pelton, AIAA, 1633 Broadway, New York NY 10019, USA, 425 pp, 1984, $44.00.

In two short decades, Intelsat revolutionised the world through a complex electronic network that now routinely carries about a billion conversations a year across the oceans. It has also become the world's major TV distribution system, providing the means for 170 countries and territories to be linked instantaneously.

As a further measure, the new Intelsat VI satellite will have a capacity 160 times greater than that of the diminutive Early Bird, which started it all in 1965. The volume of traffic has increased from 75 satellites circuits then to nearly 35,000 circuits today, plus nearly 40 transponders for domestic service in 25 countries.

These facts are just a few of those contained in the 15 contributions of this volume, ranging from an historical perspective to a contemplation of how space communications might develop over the next century. Thus, a considerable amount of technical information is interspersed with visions both past and present, a combination which makes for potent reading and provides a volume of considerable interest.

Isaac Newton: Reluctant Genius

D. C. Ipsen, Enslow Publishers, P.O.Box 38, Aldershot, Hants, GU12 6BP, 93pp, £11.95.

Newton's brilliance was recognised by his contemporaries but he was frequently hesitant to reveal his ideas for fear of the controversy they might arouse. For example, when he created calculus, he let it be known that he had made an exciting mathematical advance but told no-one exactly what it was!

This is a book which explains clearly and simply Newton's major discoveries, including the spectrum, the reflecting telescope, calculus and the law of gravitation.

Newton, regarded by many as the greatest scientist of all time, is revealed as a solitary figure.

DO YOU REMEMBER?

25 Years Ago...
25 May 1961. During a joint session of the US Congress, President Kennedy declares that America should 'achieve the goal of landing a man on the Moon and returning him safely to Earth before this decade is out.'

20 Years Ago...
2 June 1966. NASA's Surveyor 1 soft-lands on the Moon's Oceanus Procellarum near the crater Flamsteed. It returns more than 11,000 photos of the surface.

15 Years Ago...
6 June 1971. Cosmonauts Dobrovolsky, Volkov and Patsayev are launched aboard the Soyuz 11 spacecraft on a 23 day visit to the Salyut 1 space station. The three cosmonauts die while returning to Earth due to sudden cabin depressurisation.

10 Years Ago...
10 June 1976. Marisat 2, the second commercial maritime communication satellites, is launched by a Delta. Built by Hughes and operated by Comsat, the satellite is positioned over the central Pacific.

5 Years Ago...
31 May 1981. Rohini 2, India's second satellite, is launched into a lower than planned 364 x 181 km orbit. The low orbit leads to reentry eight days later.

K.T. WILSON

Locating Comet Halley

The precision navigation of the ICE spacecraft to its encounter with Comet Giacobini-Zinner was described in the January edition of this column. There it was seen that the task of navigation consisted of two components: determination of the orbit of the comet relative to Earth and determination of the orbit of the spacecraft, also in an Earth-referenced frame. The conjunction of these results yielded the targeting of the spacecraft relative to the comet. Had there been a camera aboard ICE, direct information concerning the relative location of spacecraft and comet could have been obtained.

In the case of the Halley encounters, the situation was more complex. Not only did the ESA spacecraft Giotto, and the two Vega spacecraft of the Soviet Union have cameras, but the Soviet vehicles, encountering Comet Halley first, served as navigational pathfinders for Giotto, which made a very close encounter with the nucleus of the comet.

Some aspects of this effort, which involved ESA, the Soviets and JPL, will be told in a subsequent column. Now, the work invested in the determination of the ephemeris *per se* of Halley's comet will be examined.

Dr. Donald Yeomans of JPL, an international authority on comets, used observations of Halley's comet from 240 BC up to the eve of the Giotto encounter in order to define the comet's long-term dynamical behaviour.

Working with Dr. Tao Kiang of the Dunsink Observatory outside Dublin, Ireland, Yeomans combined ancient Chinese observations with modern data to produce a long-term ephemeris for Comet Halley. Indeed, using numerical integration methods on a digital computer, they have extended this ephemeris back to 1404 BC and identified ancient Chinese observations of the comet back to 240 BC.

The principal utility of the older observations is to fix, with some exactitude, the time of the comet's closest approach to the Sun (perihelion); the shape and orientation of the orbit vary closely and predictably with time. The Chinese observations specified in what "lunar mansion" Halley's comet was located as a function of time. This is equivalent to giving its approximate right ascension (location on the celestial equator), a measure which is quite sensitive to the comet's perihelion passage time.

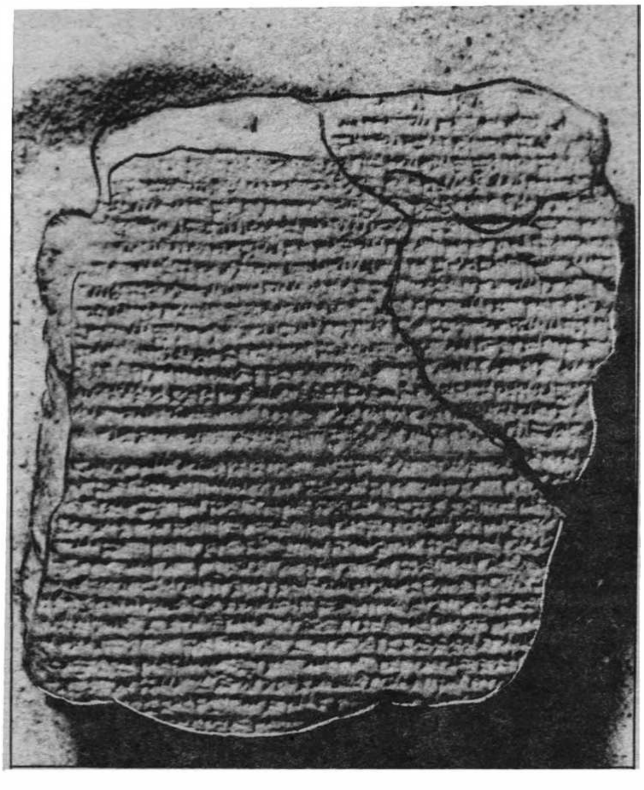
In their paper on the cometary ephemeris (see *Monthly Notices of the RAS* 197, 633-646, 1981), Yeomans and Kiang remark, "... it is curious why the favourable apparition in 164 BC went unobserved in September and October of that year." Recently, Dr. F. R. Stephenson, of the University of Durham, and his colleagues examined inscribed Babylonian clay tablets in the British Museum and discovered a record of the missing 164 BC apparition (plus a Babylonian record of the 87 BC apparition). When they compared these observations to the integrated ephemeris of Yeomans and Kiang, the agreement was excellent.

Yeomans is one of four Discipline Specialists in astrometry, the science of celestial position measurements, for the International Halley Watch (IHW). In this capacity, he set out to refine Comet Halley's ephemeris to support the 1986 exploration of the comet by the international fleet of five spacecraft: one European, two Soviet, and two Japanese.

The observational support for this network came from a collection of 124 observatories in 37 countries. Many of the observers were also participants in the Giacobini-Zinner work. Nearly one third of the observations originated in the Soviet Union, and a large number also came from Japan. As the data arrived, the orbit of the comet was continually refined.

The data from Yeomans' network were sent to the ESA Operations Centre at Darmstadt, Federal Republic of Germany, via a direct computer link from JPL, along with updated cometary orbits for comparison with European calculations. Similarly, data and orbits were forwarded by telex from JPL to Kiev (and then to Moscow) and, indirectly, via the Darmstadt link to

Fig 1 This Babylonian clay tablet in the British Museum contains records of early observations of Halley's comet. The records were recently identified and have been utilised in computer simulations of the motion of the comet, supplementing ancient Chinese and modern observations.
British Museum



Moscow. The Japanese received only orbits from Yeomans.

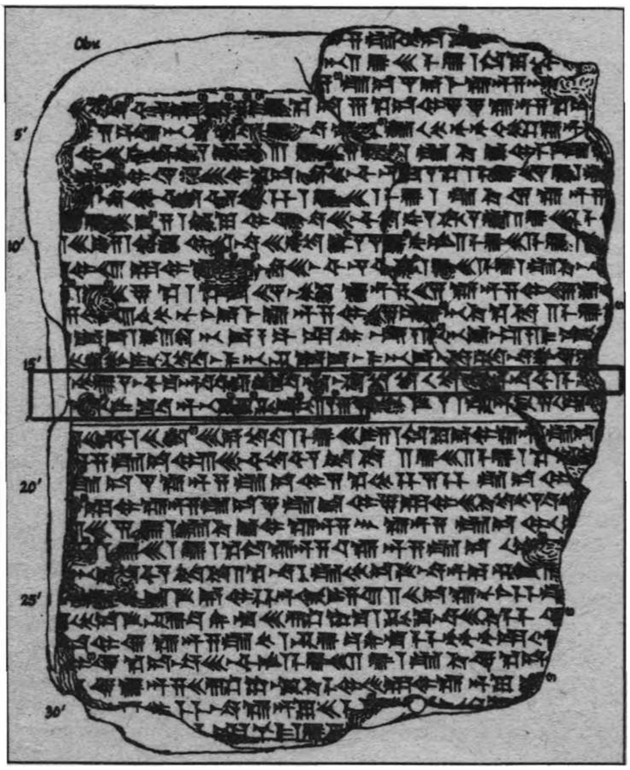
The astrometric system was tested by exercising the participants and communication lines of the IHW astrometry network through observing Comet Crommelin in early 1984. Then, in June of 1984, a workshop was held at the European Southern Observatory Headquarters in Garching, Federal Republic of Germany. The results of the workshop have been collected in the NASA publication: *Cometary Astrometry,* edited by Yeomans, *et al.*

Accurate locations of stars near the comet's path are needed so that the position of the comet on photographic plates can be accurately inferred. For this purpose special star catalogues were prepared by the Lick Observatory in California and the US Naval Observatory for distribution to members of the astrometry network. The positions of the selected stars were measured to within approximately one third of an arc second, an exactness which was necessary to support the high quality work of the astrometric observers; they measured the comet's position to within about one arc second.

For the 1986 predictions, the results of the astrometry network were statistically blended with newly reduced observations from the 1835 and 1910 returns of Halley's comet. The modern reductions of these older observations utilised better determined star positions that exist today (the FK4 system). The use of this 150-year data arc represents a compromise between employing enough data to obtain accurate results and yet not processing very old data (pre 1835) which are dynamically irrelevant to 1986 predictions.

The orbit-determination process went smoothly until after Comet Halley passed perihelion. Then the agreement between the observed and calculated positions of the comet became poor. From his two-millennia experience of Comet Halley, Yeomans knew that this particular comet was well behaved and not likely to have its orbit unexpectedly altered by perihelion passage. Thus, the discrepancy must be due to an observational effect. It turned out that the centre-of-light, with respect to which observers reported the comet's position against the stellar background, was appreciably offset from the comet's centre-of-mass, which governs its dynamical behaviour. Before perihelion the line of offset was more or less along the line of sight as viewed from Earth; after perihelion the offset was more perpendicular to the line of sight.

Fig. 2 The portion of the cuneiform writing that relates to observations of Halley's comet is indicated. *British Museum*



The offset, about 1100 km when the comet was at Earth's distance from the Sun and which varies inversely as the square of the distance from the Sun, was factored into Yeomans' orbit determination, and the agreement between observations and calculations was restored to its pre-perihelion exactitude.

Earth-based observations succeeded in placing the position of Halley's comet in very nearly the same place for the Giotto encounter as did the Vega/Giotto effort. Of course, the statistical uncertainty of the Earth-based work was larger (approximately 250 km, one-sigma).

The determination of the orbit of Halley's comet has proved to be a successful enterprise with significant historical interactions and astronautical applications.

PROTECTING VOYAGER

During the recent Voyager flyby of Uranus the emphasis was, of course, on how to extract as much science as possible from the November 4 through February 25 planetary encounter period.

Nevertheless, as with all missions, it was necessary to divert some resources from preparation for normal operations in order to provide protection against anomalies. Two fundamental considerations guide contingency planning: spacecraft health must be protected, and critical mission activities must be protected. In both cases the degree of protection is tied to the severity of the threat, the estimated probability of its occurrence, and the availability of counter measures.

The first layer of protection against any type of problem comes from an experienced, well-trained flight team. It has been almost nine years since the two Voyager spacecraft were launched, so that the potential for a depth of experience is certainly available. However, longevity brings problems as well as opportunity: people move to other jobs, retire, die, or wish to change assignments within the Voyager project. Thus, long-range staffing plans have to be developed to insure a proper mix of new and old.

For the Uranus encounter, approximately 40 per cent of the flight team had been onboard for the encounter with Saturn in 1981. Some aspects of the formal training for Uranus were discussed in the July/August 1985 edition of this column. Each individual on the flight team was formally certified for encounter operations; individual courses of training were prescribed and completion was signed off by myself or other elements of project management when he or she had run through the curriculum. Part of the training facilities included about 30 videotapes on various Voyager technical topics. 'Most of these were produced specially for the Uranus encounter and addressed topics such as the telecommunications system, the imaging system, navigation, etc.

But there are static elements to defense as well as dynamic preparedness. The Voyager project has

indentified approximately 75 situations for which remedial spacecraft procedures have been developed, in advance of their occurrence, and documented in a contingency handbook. Examples include instructions as to how to proceed in diagnosis and correction if telemetry data from the spacecraft suddenly become unintelligible or if a thruster begins to leak. In addition, files of contingency commands have been created and can be radioed up to the spacecraft on short notice to address a variety of problems. For example, a file has been created and sent to the spacecraft if it should become necessary to halt the ongoing programme of activities that are directed by the onboard computer. The spacecraft would remain in this neutral state until further instructions are received from Earth.

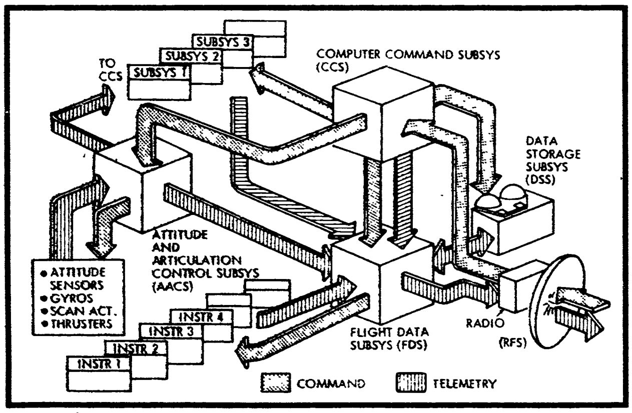
Two other modes of protection are important – computer programs and subroutines always resident onboard the spacecraft, and programs on the ground which are available for transmission to the spacecraft should the need arise (the latter programs are distinguished from contingency commands by their greater scope of action).

Voyager nomenclature speaks of Fault Protection Algorithms (FPAs) to describe programs onboard the spacecraft which render first aid until human intervention can occur. The long round-trip light times (5½ hours for Voyager 2 at Uranus) make such protection mandatory. One FPA monitors the amount of power being utilised by the spacecraft and if it is excessive certain electrical devices are switched off to reduce the load. Another FPA guides the spacecraft back to lock on its principal celestial reference source, the Sun, should that lock be lost.

A very special onboard protection program is celebrated in Voyager lore as the Backup Mission Load (BML). The need for the BML arose in 1978 when the primary receiver on Voyager 2 failed; the spacecraft now operates on its secondary receiver (Voyager 1 has both receivers intact and does not carry a BML). The purpose of the BML is to provide a set of instructions to the spacecraft which would allow it to carry out the next phase of its mission automatically should the remaining receiver fail and, thus, commandability from Earth be lost.

The BML is not just one entity, rather its content and character vary with the phase of the Voyager mission. During most of the interplanetary cruise from Saturn to Uranus, the BML was quite large. Of the approximately 2500 words (each of 18 bits) available for sequenced activities in the Computer Command Subsystem (CCS), 1000 words were claimed by the BML. Three quarters of this BML was designed to conduct an autonomous programme of observations at Uranus and radio the results back to Earth, while the remainder

Voyager's three computer subsystems



of the BML would have directed the spacecraft's study of the interplanetary medium prior to the all-robot encounter with Uranus. The BML was kept up to date by periodically adjusting its parameters as continual processing of tracking data yielded improved navigational estimates of Voyager 2's path through the Uranian system.

In March 1985, the cruise portion of BML was removed since most of the cruise phase was completed, and more sequencing space was needed in the CCS to conduct encounter-related activities. Then, in October the remainder was taken out, except for a 100-word micro-BML which yielded some protection up to when it was removed a few weeks before the January 24 encounter.

Protection against the consequences of a receiver failure on Voyager 2 is once again in place, and a minimum programme of observations would be automatically carried out at Neptune. The project is currently building a larger BML of about 1000 words which will be sent up to the spacecraft in September. Like its Saturn-Uranus predecessor, it will have the capability of carrying out an extensive programme of scientific investigations, including imaging, at the planet should it ever be invoked by the spacecraft (Voyager 2 would activate its BML if it had received no commands from Earth for a specified period of time – usually on the order of a few weeks).

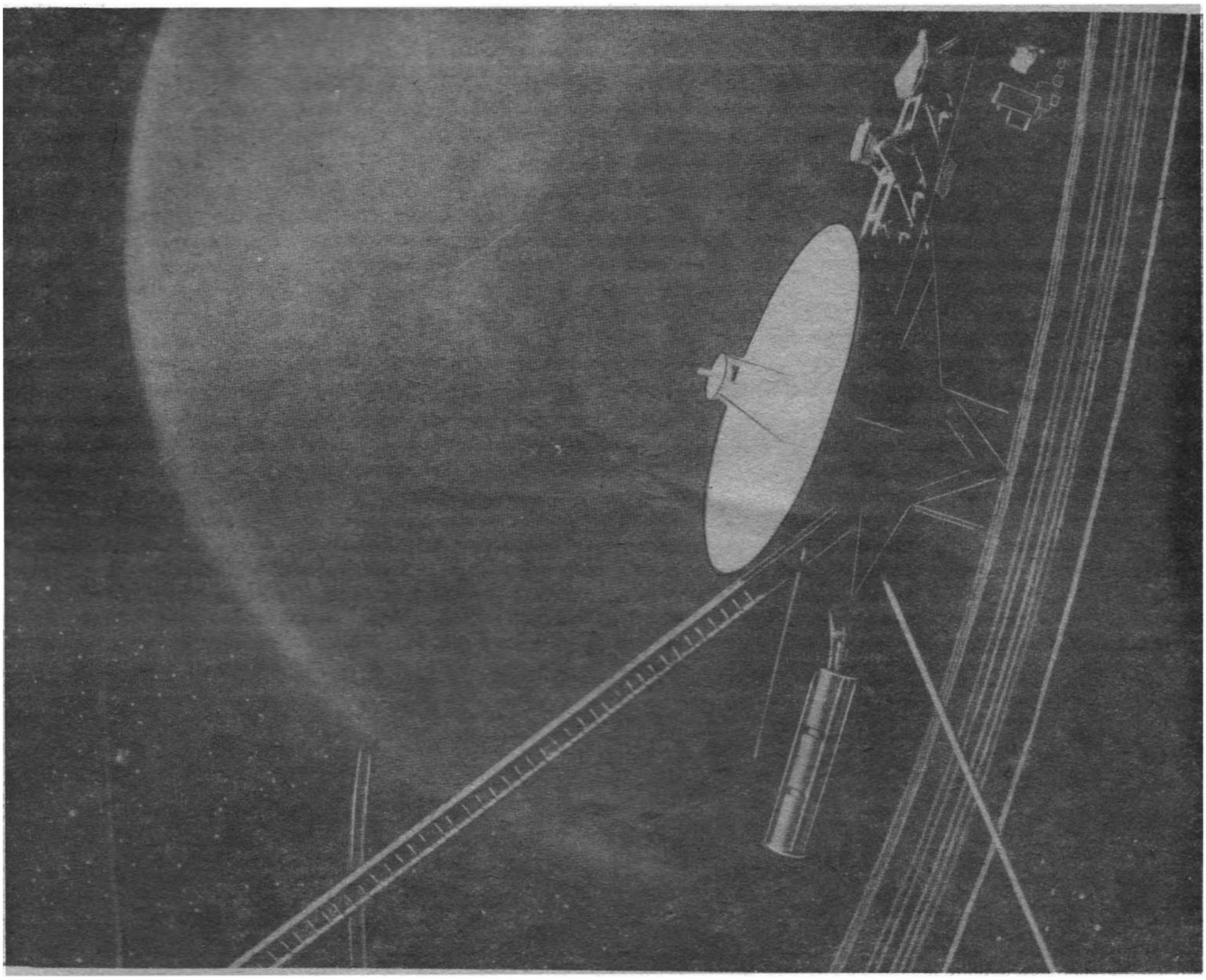
The reason that this larger BML was not readied earlier is that preparations for the Uranus encounter took precedence. Any insurance policy, for human or for spacecraft, must be evaluated on a cost versus benefit basis.

The debate over what major, special protection should be provided for the Uranus encounter was an extensive topic within the Voyager project during the cruise from Saturn. Three principal threats were identified: (1) one of the two CCS might fail, (2) a second type of onboard computer, the Flight Data Subsystem (FDS), might lose all or part of one of its two memories, (3) a gear train which seized just after the closest approach of Voyager 2 to Saturn might seize again. The significance of the gear problem is that this device activates the scan platform of the spacecraft in one of its two degrees of freedom. Four remote sensing experiments, including the two cameras, are located on the scan platform. This so-called azimuth actuator, like its counterpart system of a motor and gears, the elevation actuator, was critical to the encounter.

The probability of failure for each of these three devices was judged to lie somewhere between one per cent and five per cent, and any of these failure modes could prove to be extremely threatening to the encounter.

Each of the three possible problems was addressed in a similar manner: a substitute computer load was prepared and held ready on the ground to send up to the spacecraft should the need arise. These three substitute loads, customised for each failure mode, would have operated the spacecraft in such a way as to collect the maximum scientific information with the remaining capacity. In the case of the azimuth actuator, motion of the entire spacecraft about its roll axis would have been substituted for motion of the scan platform in the azimuth direction.

The preceding topics do not exhaust the subject of protecting Voyager; ground-computer simulations, formal procedures and rules, and a lot of tender loving care is applied to protect NASA's most productive scientific facility.



Voyager 2 just minutes from Uranus closest approach in January 1986. The picture is part of an original painting by ***Julian Baum,*** *Science Photo Library.*

Radio Science Sheds Light on Uranus

Planetary exploration by spacecraft employs such familiar tools as cameras, ultraviolet and infrared sensors, and devices to inventory the magnetosphere. However, one set of experiments, collectively known as "radio science", does not use a dedicated scientific instrument, but rather shares the radio system of the spacecraft with engineering needs.

For the Voyager encounter with Uranus, the radio science experiments investigated three areas: rings, the Uranian atmosphere, and celestial mechanics. Celestial mechanics in the radio-science context is a compound subject consisting of the determination of satellite and planetary masses, the details of the planetary gravitational field, and relativistic experiments. Other than a few notes on relativity, the celestial mechanics aspect of radio science will not be considered at this time.

The basic principles of radio science are as familiar as the activities of everyday life. Consider the act of shining a flashlight on an object in an otherwise darkened room. This "experiment" yields information about the object in an obvious way; one could expect to determine its shape, colour, and state of rest or motion. Further analysis based upon this data could uncover the structure and function of the object.

In the case of radio science, radio waves from the spacecraft are used in place of the flashlight, and their observed interaction with celestial objects replaces our simple act of seeing.

The geometrical basis of the radio-science investigation of the rings and Uranian atmosphere depended upon the fact that the spacecraft's trajectory was designed to pass behind these objects, as seen from Earth. The ring experiment derived its vigour from the fact that the ultrastable oscillator (USO) onboard the spacecraft emitted radio waves of an exact, known frequency, unlike Earth-based stellar-occulation experiments which watch a non-coherent source (a star) pass behind the rings. By analysing the distribution of frequencies received at Earth, the number of ring particles in each size range could be deduced. Both X-band (8.4 GHz) and S-band (2.3 GHz) radio signals were used in the experiment. The wavelength of the X-band waves is 3.6 cm, so information could be gained about ring particles larger than this size. In fact, most particles were found to be relatively large, on the order of one metre and larger. This difference from the rings of Saturn, which contain many very small particles, may be due to the removal of small particles from the Uranian rings through atmospheric drag, with some possible assistance from the unusual tilted magnetic field of the planet.

The atmospheric experiment was a complex undertaking; the high-gain antenna of Voyager 2 was precisely manoeuvred (in fact, the whole spacecraft was manoeuvred to accomplish this act – the antenna is rigidly attached to the spacecraft) to lay down a pattern of eight straight line segments along the limb

of Uranus, when the spacecraft was behind the planet. During this radio-science manoeuvre, X and S-band signals were being emitted from the antenna, refracted through the atmosphere of Uranus, and detected on Earth 2¾ hours later by the antennae of the Deep Space Network.

Analysis of the received signals permits a precise determination of how much they were refracted at various levels of the Uranian atmosphere. This, in turn, permits an estimate of the density, pressure, and temperature of the atmosphere as a function of distance from the limb. Combining radio science results with data from other experiments, such as infrared measurements, the composition of the atmosphere (mostly hydrogen and helium) can also be determined.

The radio-science atmospheric measurements reached down to a depth of two or three bars pressure

On more than one occasion the radio signal from the spacecraft was interrupted by methane clouds floating in the atmosphere. The signal did not penetrate deeply enough to encounter ammonia clouds, which were detected at Jupiter and Saturn, much less water clouds which may exist at even lower levels.

Although Einstein's theory of general relativity has passed every experimental test to which it has been subjected, the process of empirical testing continues. At Uranus the USO, which is unique among spacecraft oscillators for its stability, was employed in a gravitational red-shift experiment. The X-band radio signal was measurably altered in frequency by the gravitational field of the planet.

In early December Voyager 2 passed behind the Sun, as seen from Earth. The radio-science experimenters utilised the apparent proximity of the spacecraft to the Sun, and the consequent close passage of radio waves to that body, in order to investigate the solar corona (especially plasma density profiles and their short-term variations, and electron densities). During the solar-occultation experiment, which took place for about two weeks before and after the actual occultation, relativistic experiments were also conducted.

The Team Leader of the Voyager Radio Science Team is Dr. G. Leonard Tyler of Stanford University. Thanks are due to Donald Sweetnam of JPL, Chief of the Radio Science Support Team, for conversations on this subject.

Environment Watch

The same spacecraft that provide the all-too-familiar satellite pictures of cloud patterns for our weather forecasts are also capable of fulfilling many other less well publicised but nevertheless important monitoring roles. These relate to snow cover assessment and mapping, sea ice, river flooding, soil moisture analysis, fire detection and the progress and changes of vegetation.

The TIROS-N satellite series is one of the civil polar orbiting systems collecting environmental data. Currently four such satellites, designated NOAA 6, 7, 8 and 9 and launched in 1979, 1981, 1983 and 1985 respectively, are operating in orbits at an altitude of 850 km.

Most European countries have direct access to the Automatic Picture Transmission (APT) offered by the TIROS Satellites, but few are able to access and process the digital High-Resolution Picture Transmission (HRPT) service, which is used to transmit both the Advanced Very High Resolution Radiometer (AVHRR) image and the TIROS Operational Vertical Sounder (TOVS) data stream.

The AVHRR has five wavelength channels namely (1) 0.58 – 0.68 μm; (2) 0.725 – 1.1 μm; (3) 3.44 – 3.93 μm; (4) 10.3 – 11.3 μm; (5) 11.5 – 12.5 μm. The characteristics of channels 1 and 2, which contribute to the colours of the photography opposite and are referred to below, are summarised as follows:

Channel 1: **visible, reflected light. Measures albedo; defines snow and ice features; terrain features; vegetative cover; and meteorological (cloud) features.**

Channel 2: **near infrared. reflected infrared. Defines snow and ice condition and melt; allows vegetation assessment, being highly sensitive to the presence of chlorophyll; and meteorological (cloud) monitoring.**

* * *

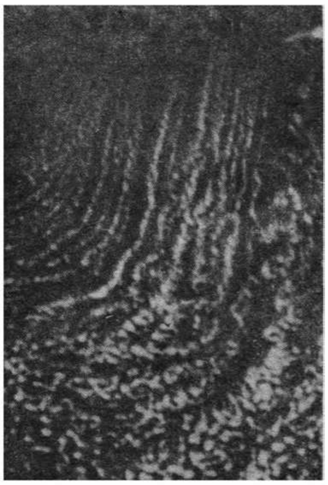
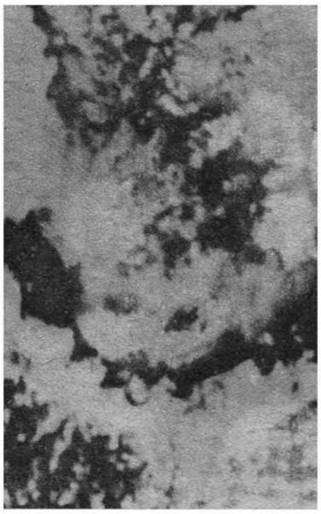
The image (right) shows Western Europe and Northern Africa as seen from NOAA-9 (March 27, 1985, 13:25 UT), covering an area of approximately 3000 km (E/W) by 5500 km (N/S)

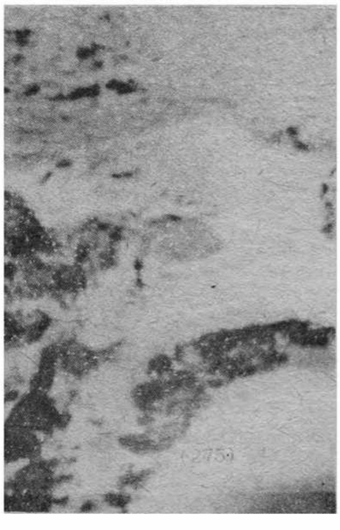
HRPT data such as this from NOAA satellites are received operationally on a daily basis and processed by DFVLR, Germany.

The four segments on the right-hand side of the picture represent enlarged subsections of the satellite's pass for selected areas with particular phenomena.

These are (from top): Kasman Vortex south of island of Jan Mayen; cloud structures north-west of Scotland; and the deserts of Sahara and Libya.

The colour signals for red, green and blue are produced from AVHRR channels 1 and 2 mainly. The green colouring of land – except for desert areas – is produced by the higher reflection of vegetation in channel 2, whereas the reflection of channel 1 is higher for ice. Thus snow-and ice-covered areas in Iceland, Norway, the Alps and the Pyrenees are represented by light blue. Even the frozen surface of the Baltic Sea and Bottenvik can be seen through transparent clouds. In the North African deserts, the lower reflection in channel 1 makes the 'green' of vegetation and settlements appear darker than in arid sand desert areas.

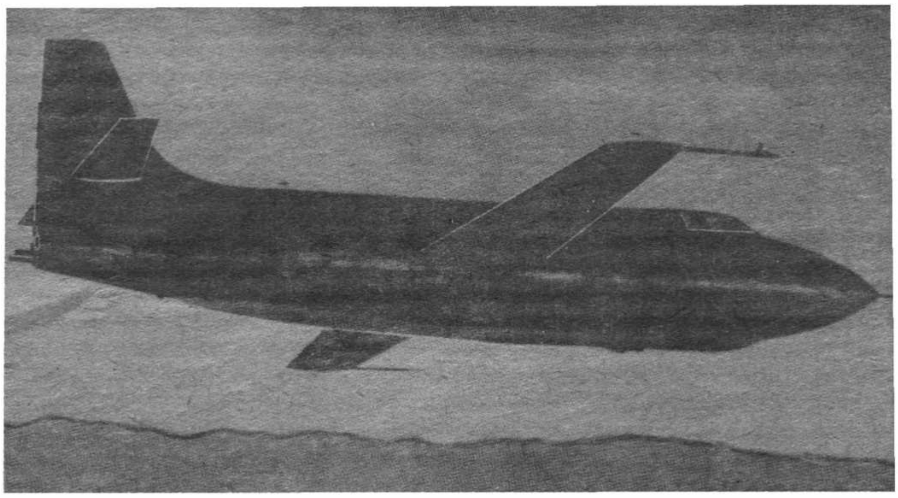






On Wings Into Space

by Curtis Peebles

Under an endless blue sky amid the vast expanse of the Mojave Desert is the Ames-Dryden Flight Research Facility. In the four decades since its founding in 1946 its pilots, engineers and researchers have been in the forefront of the advancement of flight. Here the X-1 first broke the sound barrier. Later, other rocket aircraft pushed back the frontiers of speed and altitude. It was here too that the process reached its logical conclusion with the return to Earth of Columbia after its first flight into space.



Designed and built by Bell Aircraft Corporation for the US Air Force, the X-1A reached a top speed of 1650 miles an hour. 2.5 times the speed of sound – and an altitude of around 90,000 feet.

The Early Years

Several threads came together to shape the history of Ames-Dryden. The first was the advances in aircraft made in the late 1930s – more powerful engines, better fuel and refined aerodynamics meant planes could now approach the speed of sound. At such speeds, however, shock waves formed, turbulence battered the plane and control became marginal. Airplanes were torn apart and pilots died. Wind tunnels were also affected meaning the problems could not be studied. An idea developed that the speed of sound was a wall in the sky barring further progress – a sound barrier.

To probe this unknown a special research aircraft would be built, designed from the start to face these speeds. Previously, high speed testing had been done with converted fighters making steep dives toward the ground, clearly a dangerous procedure. With a rocket engine, the speed run could be made at high altitude and in level flight. This would lessen stress on the aircraft. This plane would become the X-1.

The second trend was the need of the Army Air Force for a new flight test centre. Since World War I, Army activities had been concentrated at Wright Field outside Dayton, Ohio. The area was now heavily urban, posing dangers from a safety and security viewpoint.

The final trend was geographic and geological. In the Mojave was Rogers Dry Lake. It was the largest dry lake in the world. Rogers' huge flat expanse would soon become the world's largest airfield. The area also had the advantages of nearly year round flying weather and close proximity to the aircraft plants that began to spring up around Los Angeles in the 1930s.

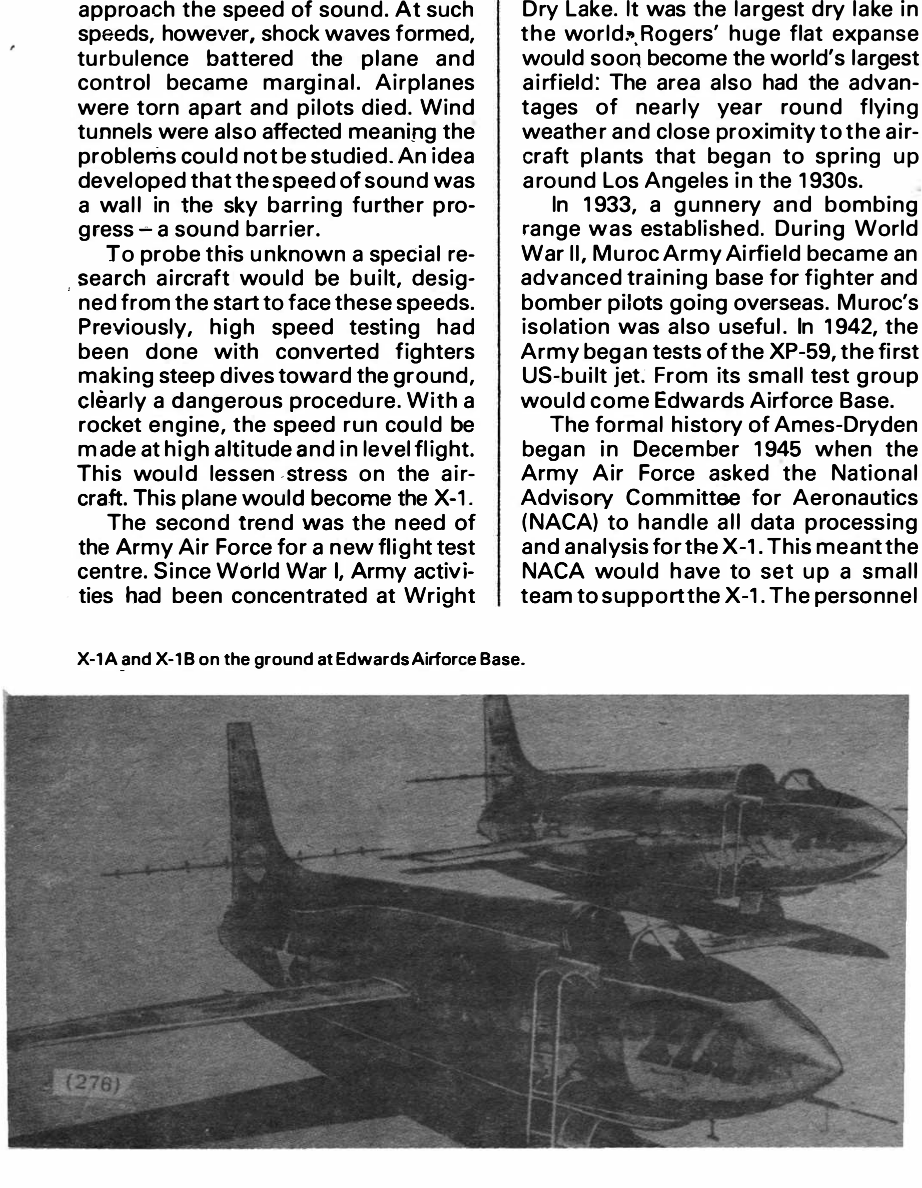
In 1933, a gunnery and bombing range was established. During World War II, Muroc Army Airfield became an advanced training base for fighter and bomber pilots going overseas. Muroc's isolation was also useful. In 1942, the Army began tests of the XP-59, the first US-built jet. From its small test group would come Edwards Airforce Base.

The formal history of Ames-Dryden began in December 1945 when the Army Air Force asked the National Advisory Committee for Aeronautics (NACA) to handle all data processing and analysis for the X-1. This meant the NACA would have to set up a small team to support the X-1. The personnel would come from the Langley Research Center*. The leader of the group was Walter C. Williams of the stability and control branch at Langley. On September 30, 1946 he and four engineers arrived in the desert. They were followed in October by six more engineers and finally in December 1946 by two "computers". In the pre-electronic age, "computers" were humans (invariably female) who performed the laborious calculations needed to reduce the instrument readings. They were called the Muroc Flight Test Unit.

This first small group faced many hardships. Muroc AAF, in the early post-war years, was a bleak, harsh place. Housing was very poor, some was called "Grade A fire traps". Facilities were not much better. NACA shared the East Main Hanger with the Air Force. The only office space was two small rooms. There were no dark room facilities and inadequate shop and stock space. Blowing dust in the open hanger threatened to contaminate the instruments.

All this plus the heat, cold, hours of overtime and loneliness (Los Angeles was an all night bus ride away) meant a high turnover, poor morale and difficulty in finding replacements. The underlying reason was the mass demobilisation at the end of World War II. There was simply no money to improve or even maintain the wartime facilities. Williams' hopes to improve the facilities and housing also faced problems with the local Air Force authorities. The base commander feared giving NACA separate facilities would delay an ambitious master plan for expanding the base into a full scale flight research centre. This involved

X-1A and X-1B on the ground at Edwards Airforce Base.



*One trend in the history of NACA/NASA is that field centres tend to be spun off from Langley. Another example is the Lyndon B. Johnson Space Center.

building a new runway, a new hanger and office complex, as well as a housing area with schools and shopping centers. The problem was taken up at the NACA Main Committee where the Air Force Members supported the NACA position. NACA received exclusive use of a hanger in April 1948. Leán-to offices and shops were built along its side. These were completed in November. By the spring of 1949, the men's and women's dormitories were competed. [1].

The Golden Years

The new decade of the 1950s saw many changes. On January 27, 1950 Muroc was renamed Edwards AFB. With the new name came an expanded role. The master plan was put into effect with the construction of the new South Base. The NACA facility was also moved to a location midway between North Base and the new South Base. Ground was broken on January 27, 1953. There were to be two large hangers and an office building inbetween. It would form the core of today's Ames-Dryden. Work was completed in early 1954 and the new facility was named the NACA High Speed Flight Station. It also cut its links with Langley and became an independent centre.[2]

These years are often called the golden age of flight testing. Between the mid-1940s and the end of the 1950s, aircraft speed and altitude would be tripled over those achieved during World War II. Never before or since, has aviation technology undergone such a growth. Although Chuck Yeager and the X-1 on October 14, 1947 had proven an aircraft could achieve supersonic speed there remained many unknowns about aerodynamics, aircraft systems and stability and control.

To probe these, NACA operated a wide variety of research aircraft. Rocket powered aircraft were the second Bell X-1 (later rebuilt as the X-1E), the X-1A and X-1B and the Douglas D-558-II Skyrocket. In one of these, NACA pilot A. Scott Crossfield on November 20, 1953 became the first to reach Mach 2. Jet powered aircraft were also used - the Douglas D-558-I Skystreak, Douĝlas X-3, Northrop X-4, Bell X-5 and Convair XF-92A. These represented a wide variety of configurations (XF-92 delta, X-4 swept wing no tail, X-5 variable sweep, D-558-I straight wing).

NACA also worked with the Air Force, both in designing the research aircraft telemetry packages and by testing military fighter aircraft, the F-89, F-100, F-101, F-102, F-104, F-105 and YF-107. Perhaps the most important of these tests were on the F-100. In 1954, several F-100s broke up during manoeuvres. NACA flight testing found they had fallen victim to "inertial coupling". Because of its long fuselage and small fin, the aircraft had a tendency to go into simultaneous roll, yaw and pitch. The solution was increasing the size of the fin. Subsequently, a large fin (and later dual fins) became standard for high speed aircraft.[3]

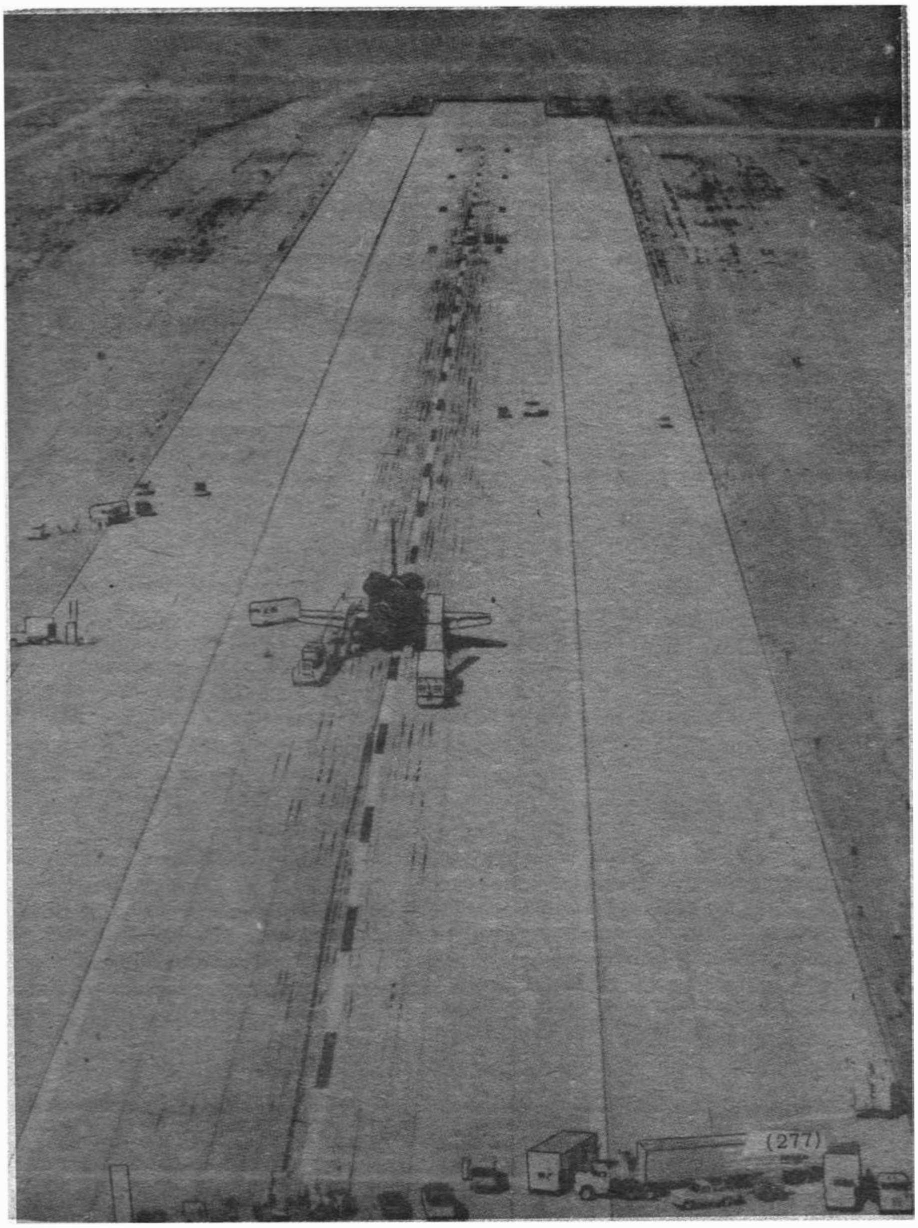
Into Space

As the 1950s passed, an increasing amount of the staff's time at the High Speed Flight Station was directed towards space studies. Some of the areas were flight above Mach 5, reaction control systems and winged spacecraft. This trend was further accelerated by the launch of Sputnik.

The golden years had taken aviation from Mach 1 to the highest fringes of the atmosphere. It was now time to make the leap into space. The research aircraft that would do this was the X-15. Early studies had been done at the High Speed Flight Station in 1952-53. NACA approved development in 1954. Its performance was to be Mach 6+ and a maximum altitude of 76,000 m. (To put this into perspective, the first Mach 2 flight had been made two years before and the first Mach 3 flight was still two years in the future). In September 1955 North American Aviation was selected to build the X-15.

At the same time, the High Speed Flight Station was also preparing for the coming of the X-15. Earlier rocket aircraft were dropped from their carrier aircraft only a short distance from Edwards. Tracking facilities at Edwards were sufficient. For the X-15, a much more extensive network would be needed. In 1956, construction began on the High Range. It stretched 780 km from Edwards AFB to Wendover, Utah. Tracking stations were built at Edwards, Ely and Beatty, Nevada. The stations were electronically linked and could provide precise radar data on aircraft position, altitude and ground speed.

Space Shuttle Columbia is flanked by mobile ground support equipment shortly after making a flawless fourth return from space. Crewed by Mission Commander Ken Mattingly and Pilot Henry Hartsfield, the spaceship made its first concrete strip landing on July 4, 1982 on Runway 22 at Edwards Air Force Base. The triangular shape in the background is a target aim point, like the one the astronauts used at the other end of the strip to guide Columbia in.



The flight line at Ames-Dryden in 1984. Visible are the 747 shuttle carrier aircraft, the B-52 drop plane, a 720 used in a crash test on a new fire resistant fuel additive, an F-111, a B-57, a C-47 used to tow the M2-F1, an F-15, an F-14, two sail planes, an F-8, a Jet Star business jet, a T-38 and several F-104s. Beyond is the seemingly endless expanse of Rogers Dry Lake. *NASA*

On October 1, 1958 NACA officially went out of business and was replaced by NASA. A year later, on September 27, 1959 the facility was renamed the Flight Research Center – the name it would bear until the mid-1970s.[4]

The first X-15 was delivered to Edwards in the Spring of 1959. There followed a two year long series of contractor tests – first glide, then powered flight to speeds over Mach 2. By 1960 even as the contractor flights were still underway, a joint NASA/Air Force/Navy test team had begun making research flights. Over the next three years the X-15 was pushed to ever higher speeds and altitudes. On July 17, 1962 Air Force Major Robert White reached an altitude of 95,940 m. This was the first flight by a winged vehicle above the 80 km altitude designated as the beginning of space. A year later, NASA pilot Joe Walker reached 107,960 m, the highest altitude achieved by the X-15 and a record for winged flight that would last until the coming of the Shuttle.[5]

The Flight Research Center was also looking ahead to winged orbital flight. This was to be the X-20A Dyna-Soar Program. This was an Air Force effort to build a one man delta wing glider to be launched by a Titan IIIC. Studies were made on instrumentation and air launch from a B-52 or B-70. The most significant activity was testing of the X-20A's abort profile. The aircraft used was a Douglas F-5D-1 Skylancer. (Not to be confused with the Northrop F-5 Freedom Fighter. The Skylancer was a prototype Navy fighter built in the late 1950s that did not enter production). The project pilot was Neil Armstrong. He found the best procedure was a vertical climb to 2,100 m, then pulling back on the stick until the aircraft was inverted, followed by a roll upright and a long glide to a landing.[6]

The Flight Research Center also did much of the early work with Lifting Bodies. The concept of a wingless shape that provided lift was originated at the Ames Research Center in 1951. The half cone shape was designed to withstand a Mach 25 re-entry. There were questions about its stability at low speed. In February 1962, Flight Research Center engineer Robert D. Reed decided to make some tests. He built a 60 cm model of the M-2 Lifting Body. This was released in flight from a larger radio controlled aircraft. He also flew small lifting body models down the Flight Research Center hallways. These unorthodox tests showed promise and in September 1962, Center Director Paul F. Bikle authorised development of a lightweight low cost manned M-2. Floor space in a hanger was walled off with canvas and a sign reading "Wright's Bicycle Shop" was put up. The M2-F1 was ready in early 1963. To go with this home built aircraft was an equally bizarre tow vehicle. It was a stripped down Pontiac convertible with a big engine, four barrel carburettor, stick shift, roll bars, radios, special observers' seats and air

speed [illegible] ment. It could hit 17[illegible] with the M2-F1 in [illegible] speed instruments were [illegible] a high speed run in [illegible] desert (which then had [illegible]). California and Nevada [illegible] Patrolmen were astonished [illegible] vehicle. The car was legendary for its ability to pass aircraft in flight [illegible] roaring along the lake bed.

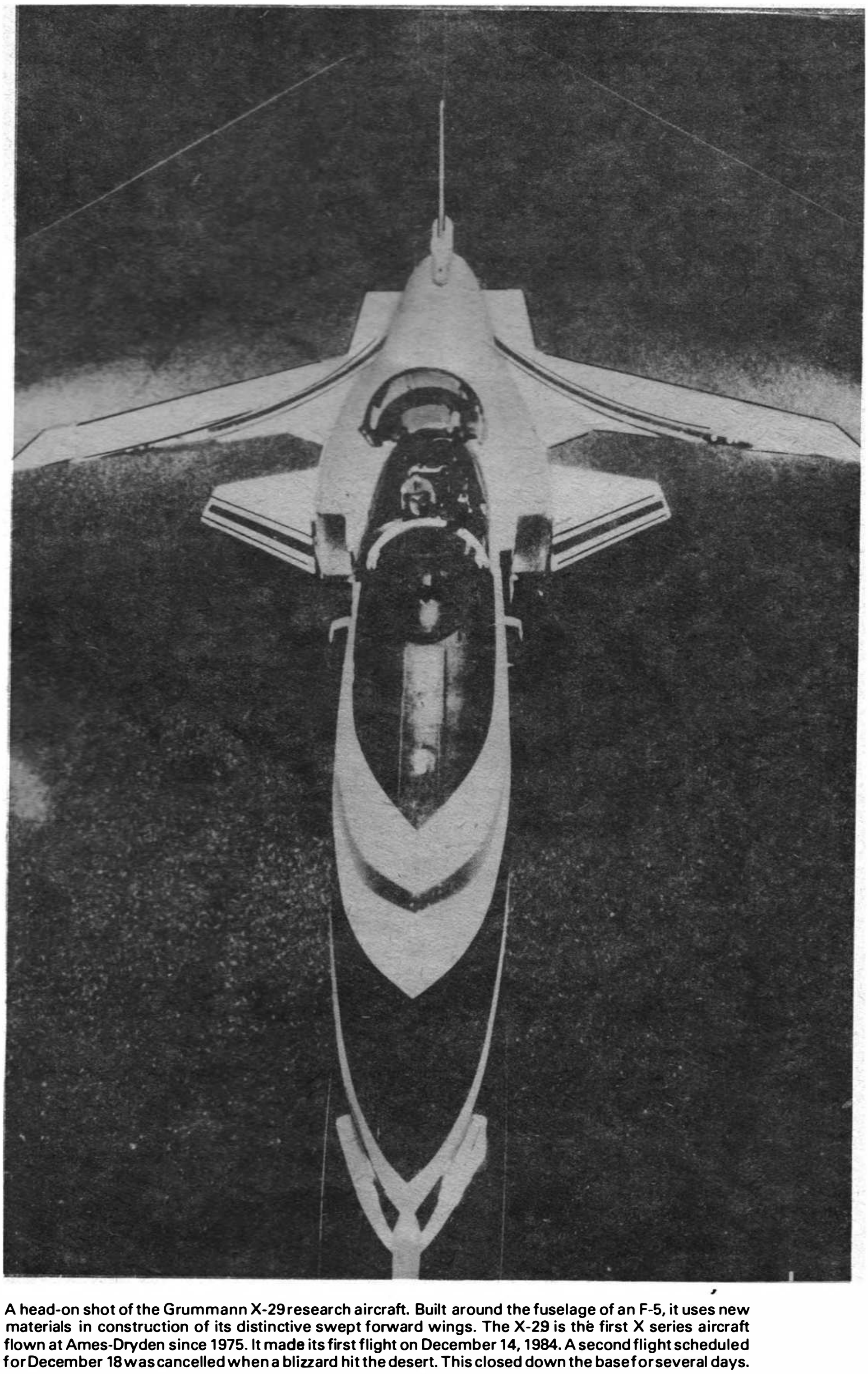
The first car tow of the M2-F1 was made on April 5, 1963 with 45 more by the end of the month. Their success encouraged the Flight Research Center to undertake tow flights behind a C-47. The first was made on August 16. The M2-F1 opened the way for testing of heavyweight lifting bodies, the M2-F2/3, HL-10 and X-24A/B between [illegible] and [illegible]. One of the tests with the HL-10 was very significant for the Shuttle. Several flights in 1970 showed it was preferable that the Shuttle should make unpowered landings. Jet engines would actually degrade safety by making the landing more difficult.

The Flight Research Center was also behind the most unusual [illegible] of the research aircraft — the Lunar Landing Research Vehicle (LLRV). It looked at the problems of simulating a landing on the airless Moon and found that a helicopter could not match the descent rate of the rocket-powered lander. The LLRV used a gimballed jet engine to support 5/6 of the vehicle's weight, two rockets to support the remainder and 16 small rockets for attitude control.

The first free flight of the LLRV was made on October 30, 1964 by Joe Walker. The two LLRVs and three Lunar Landing Training Vehicles were subsequently used to train Apollo commanders. Despite its strange appearance and touchy nature (three crashed), the LLRV/LLTVs were important for the success of the Apollo programme. They were the only way to simulate the characteristics of the Lunar Module in free flight.[8]

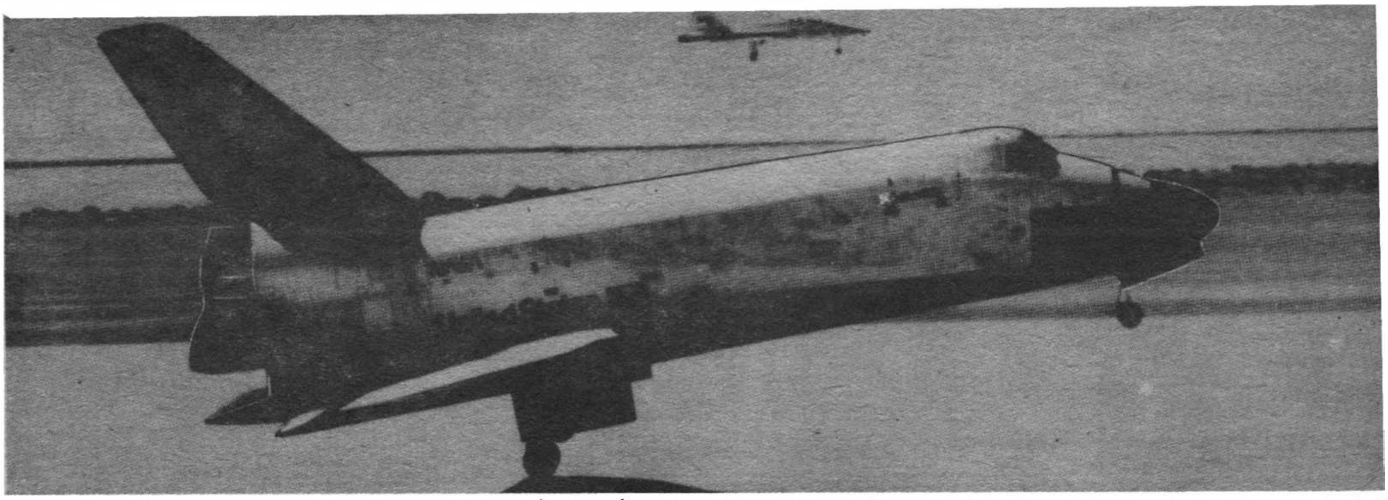
Shuttle

In 1972 as the Lifting Body flights were still underway, President Nixon approved the development of the Space Shuttle. It was the logical outcome of 25 years at the Flight Research Center. When the time came to make low speed glide flights of the Shuttle, they would be at the Flight Research Center. Construction began on a new hanger and gantry to place the Shuttle atop the 747 carrier aircraft. At the same time, the Flight Research Center underwent another name change. On March 26, 1976 it became Hugh L. Dryden Flight Research Center. Dr. Dryden had done some of the earliest work on supersonic flights. He became NACA Director of Research in September 1947 and was very influential in the development of rocket aircraft. After the founding of NASA he became Deputy Administrator until his death in 1965. He liked to say "the airplane and I grew up together".



A head-on shot of the Grummann X-29 research aircraft. Built around the fuselage of an F-5, it uses new materials in construction of its distinctive swept forward wings. The X-29 is the first X series aircraft flown at Ames-Dryden since 1975. It made its first flight on December 14, 1984. A second flight scheduled for December 18 was cancelled when a blizzard hit the desert. This closed down the base for several days.

Six months after it was renamed, the Space Shuttle Enterprise was rolled out and in January 1977 was transferred to Dryden. During the spring and summer of 1977 it made several captive flights atop the 747. Finally on August 12, 1977 the Enterprise made its first free glide flight. Four more followed in September and October.[9] Starting in 1981, Edwards AFB served as the landing site for early Shuttle missions (the exception being STS-3 which was rescheduled to White Sands because Rogers Dry Lake was flooded). Landings did not begin at the Kennedy Space Center until mission 41B in February 1984. Dryden continued to be used for the first landings of each new Shuttle, the primary emergency landing site and as home base for the 747 Shuttle carrier aircraft. After STS-51D damaged its brakes landing at Kennedy Space Center in April 1985, it was decided to resume landings at Edwards



Columbia as it touches down on the Edwards AFB runway at the end of the STS-4 mission. In the background is a T-38 chase plane and beyond it Rogers Dry Lake.

for the next few flights until the problem was better understood.[10] Mission 51L was meant to be the first to resume Kennedy Space Center landings.

Center in Transition

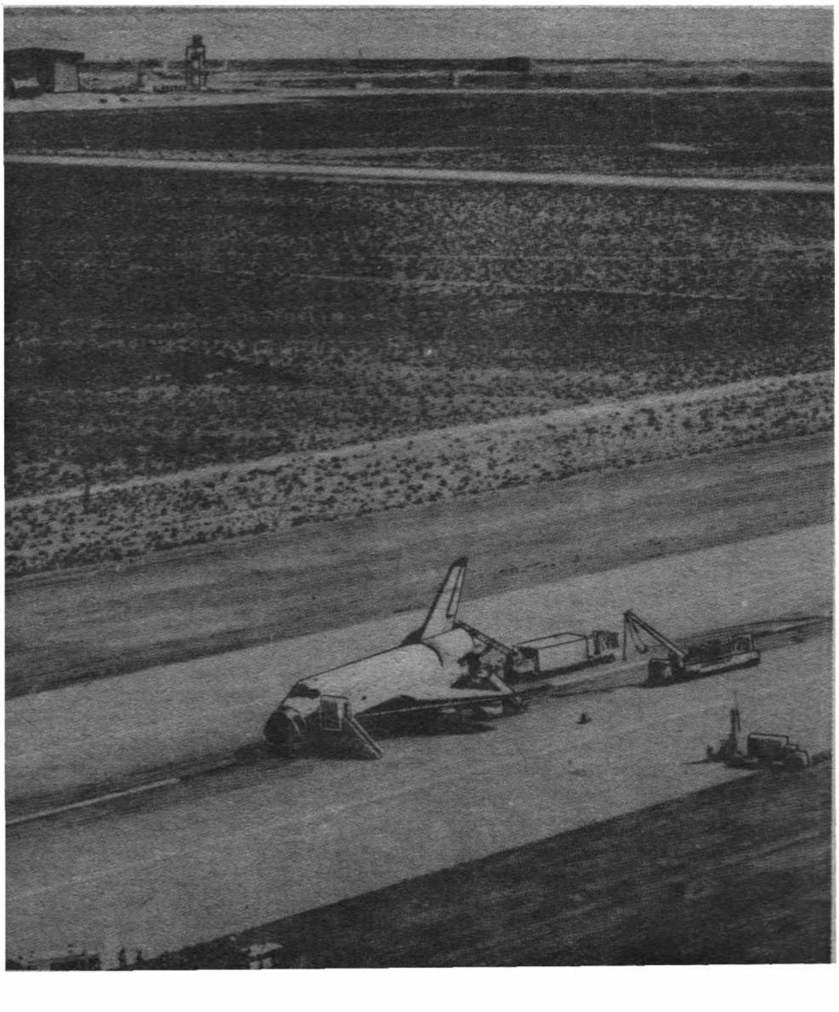
The Shuttle aside, the years following the end of the Lifting Body Program were troubled ones. A proposal to build a Mach 8 X-24C did not receive approval. Similarly, a plan to build an 11 m long sub-scale version of the Space Shuttle to test its aerodynamics up to Mach 5 went nowhere. Space research at Dryden was reduced to a few scattered projects. One was to test the ability of Space Shuttle tiles to withstand aerodynamic forces. Another was a study of the cooling of molten cast iron during Zero G. The test package, built by John Deere, was fitted in a TF-104. The tests sought improved iron products such as engine blocks.[11] Dryden has no direct involvement in the Space Station programme.

Traditional aerodynamic testing was also being phased out. The YF-12 programme ended in 1979. These changes reflect the current state of aerospace engineering. The stress is not on airframes but rather on systems and improved efficiency. Such projects include the F-8 and F-111 supercritical wing, the F-8 digital fly by wire (which used electronic controls rather than rudder cables and hydraulics). The F-111 integrated propulsion control system (which used electronic controls for the engine) and the F-111 mission adaptive wing. In the latter, the wing actually changed shape to match its speed. Two of the most exotic programmes were the oblique wing and the X-29 swept forward wing. The first has a wing pivoted in the center. It rotates as a single unit until there is a 60 degree angle between the wing and fuselage. It was first tested in the mid-1970s on the AD-1. In 1987-88, an oblique wing will be fitted to an F-8. The other has the wing swept forward. It has been known, since World War II, that a swept forward wing is actually more aerodynamically efficient than one swept back. Unfortunately until now, they could not be made strong enough within acceptable weight limits.

During the same time, Dryden was undergoing organisational changes. Soon after the first Shuttle flight, NASA began consolidating several of the smaller centers. Dryden was combined with the Ames Research Center near San Francisco. Ames history began before World War II. Establishment of a west coast laboratory was recommended in an October 1938 report. It was not until the outbreak of World War II that Congress approved. The legislation authorised expansion of the Langley Research Center, a new NACA Flight Propulsion Laboratory (later to become the Lewis Research Center) and the Ames Aeronautical Laboratory. Over the following decades, Ames and Dryden had worked together on several projects. Thus, merger was logical from both a geographic and historical viewpoint.

The merger became official on October 1, 1981. The Edwards complex was renamed the Ames-Dryden Flight Research Facility. The site manager at Dryden also acts as Director of Flight Operations at Ames.[12] Several of the flight test programmes at Ames were transferred to Dryden. Ames retained only the aircraft used in its space science and Earth resources programmes. Ames concentrates on wind tunnel testing. Dryden, on the other hand, specialises in actual flight testing of complete aircraft. Thus the parts of the new joint centre forms a complementary whole.

Columbia after touching down in July 1982 for the first time on the concrete runway at Edwards. It made contact with the ground just past the 3,000 foot marker and rolled to the 11,000 foot marker, leaving 4,000 feet to spare. Runway 22 is 15,000 feet long, the same size as the Shuttle runway at KSC.

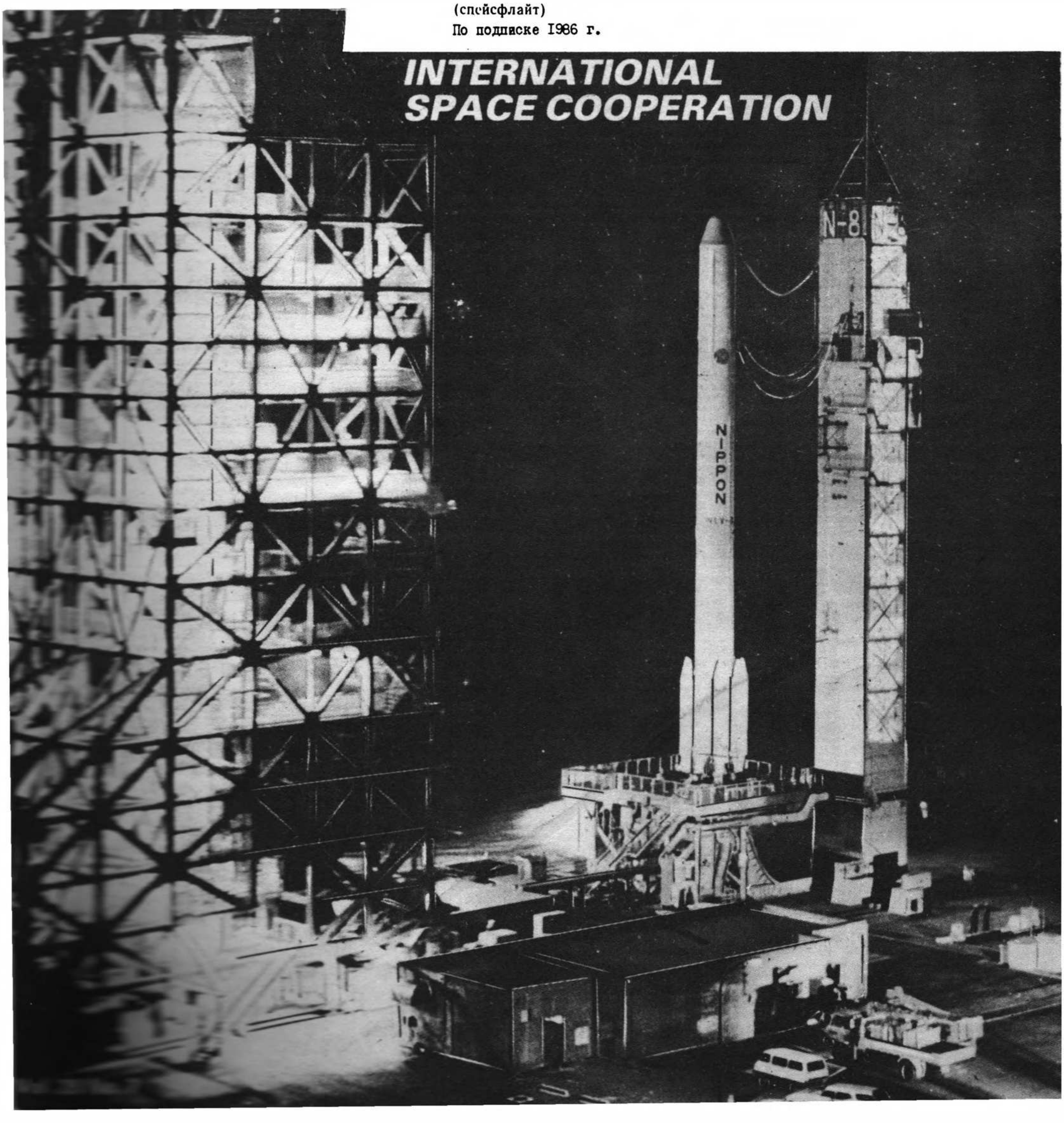


JULY/AUGUST 1986

Spaceflight

The International Magazine of Space and Astronautics

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-7-8
(спейсфлайт)
По подписке 1986 г.



CONTENTS

Editor:
Groves

Assistant Editor:
Simpson

Managing Editor:
Carter

Spaceflight Sales:
A. Jones

Advertising:
Simpson

Spaceflight Office:
South Lambeth Road,
London, SW8 1SZ, England.
Tel -735 3160.

SUBSCRIPTION DETAILS

Spaceflight is available world-wide by annual subscription. The rate for 1986 issues is £30.00 (US$50.00) inclusive of surface mail delivery. Subscribers also receive the publication *Space Education* (two issues) at no extra charge.

Airmail dispatch of ***Spaceflight*** to non European countries is available at an additional cost of £1.50 (US$2.50) per issue (1986). Air Mail dispatch is effective for the next issue of ***Spaceflight*** for orders in hand on the 14th of any month.

Back issues of ***Spaceflight*** are supplied from available stocks at £2.00 (US$4.00) each inclusive of surface mail delivery.

All orders with remittance enclosed should be sent to 'Spaceflight Sales' at the above address. Payment may be by sterling or dollar cheque made payable to B.I.S. or by GIRO (to account number 4008).

Spaceflight may also be received regularly by mail through membership of the British Interplanetary Society. Details of application are available from the Executive Secretary.

* * *

Vol. 28 No. 7 July/August 1986

Front Cover: A Japanese N-11 vehicle being prepared for launch at the Tonegashima Space Centre. The vehicle is based on the United States Delta rocket and is manufactured in Japan under licence, an illustration of commercial cooperation on an international scale. Part of the agreement means that Japan can only use the vehicle for domestic launches.

В журнале не печатается ряд страниц.

INTERNATIONAL COOPERATION

International cooperation is a key factor in the future exploration and exploitation of Space. The size and diversity of potential projects – like permanently manned space stations and the manned settlement of the Moon and Mars as proposed by the US Commission on Space – makes increasing cooperation inevitable.

A symbolic milestone of international cooperation was the 1975 link-up in space between American astronauts and Soviet cosmonauts. Since then a host of other nations have become fully involved in the space scene and although other more scientifically meaningful projects have continued there is still much to be accomplished.

In this issue *Spaceflight* highlights important aspects of international cooperation, as viewed from East and West, beginning with the article below prepared by Richard R. Colino, Director-General of INTELSAT, an organisation which has pioneered an international system of communications satellites.

"In the exploration and use of outer space ... parties to the treaty shall be guided by the principles of cooperation."

When those words were incorporated into the Outer Space Treaty in 1967, they reflected a realisation that the true challenge – the greatest barrier – to the successful exploration and use of space isn't technological but political. Little has changed.

Our technological aspirations and capabilities have grown immensely since 1967. And they continue to grow. We can do things today that were unimagined 20 years ago. Twenty years from now, we will be able to make the same statement. But inventing the future means more than just developing new technology. In our field, inventing the future means bringing space "down to Earth," and putting it in the service of humankind.

Much of the technology we need to do that is here to day, or soon will be. And demand for the benefits of space – better communications systems, more efficient manufacturing of drugs and materials, and a host of others – is just around the corner.

But despite our technological progress, and prowess, we stand at a crossroads today. Some seem to believe that the exploration and exploitation of space can be leveraged to produce a tremendous competitive advantage. They believe a national – no a nationalistic – programme will confer supremacy and superiority upon their commercial and military establishments. Perhaps that's why so much of the world's "space budget" goes to support military programmes.

But there is another road – the road of international cooperation. A road that I believe, if followed, will lead to the true benefit of humankind. As the recent Business-Higher Education Forum report on the American space effort argues:

"... space should be used as a diplomatic tool to promote cooperation and synergism among nations. [But] because these conflicting positions have not been reconciled, the potential benefits of international cooperation have not been fully realised."

Perhaps we can take a first step. The *New York Times* recent[illegible] *like a joint American-So*[illegible] *foster trust and* [illegible] *peaceful ends."* [illegible]

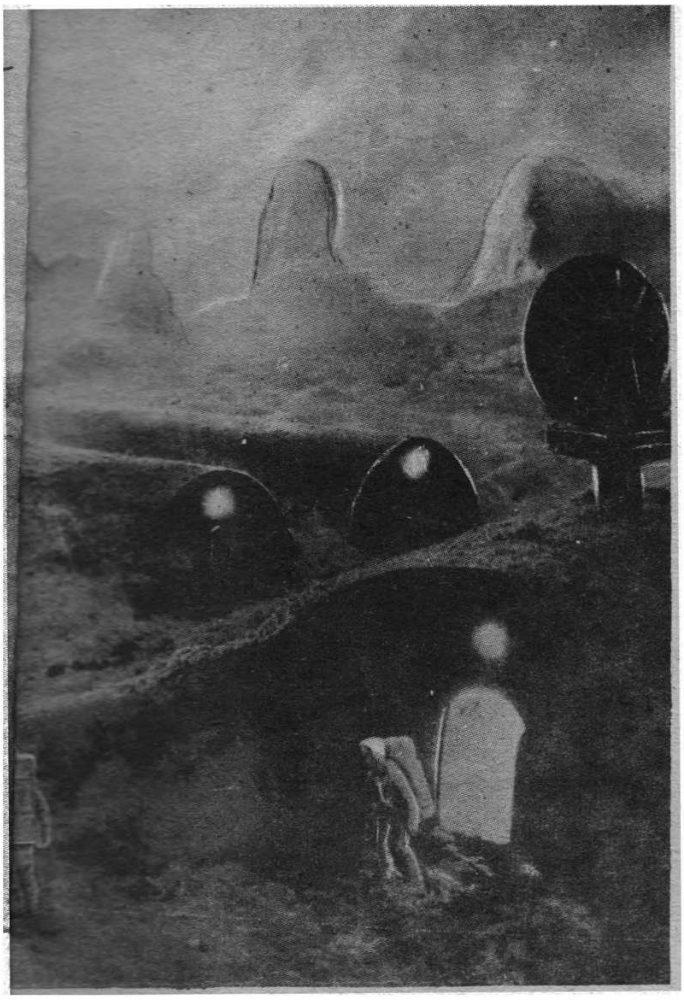
The United States Space Programme

[illegible] programmes – the United States – [illegible] birth into two [illegible] protect and nurture [illegible] raised in an era of [illegible] the civilian programme [illegible] promote international cooperation [illegible] Farsighted programmes [illegible] a satellite to India [illegible] educational programmes [illegible] – reaped a bountiful harvest [illegible]

And the United States [illegible] accomplishments [illegible] President Kennedy promised [illegible] the end of the 1960s [illegible] it? Many Americans [illegible] Yankee ingenuity [illegible] scoffed. In 1969, [illegible] when they [illegible] historic first step on the Moon.

But the US space programme seemed to lose some of its [illegible] ended. The [illegible], as the *New*

– NEW INITIATIVES IN SPACE

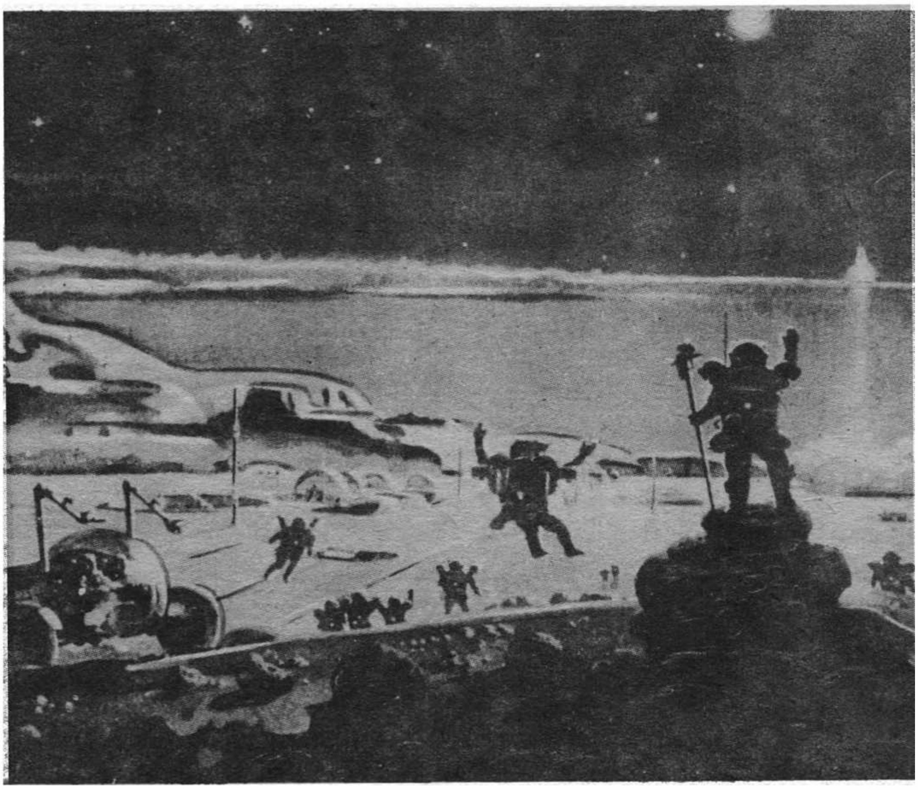


York Times recently put it, an "obsession with means ... instead of ends." But, continued the *Times,* "the Shuttle failed to meet ... (its) promise ... and when the means failed catastrophically on January 28, the policy collapsed with it." Of course, despite that terrible tragedy in January, the Shuttle has, to my mind, been a success. But it is a contradiction: the Shuttle carries people, which makes it very expensive, even though it is supposed to be an inexpensive way to launch satellites.

In a larger sense, the *Times* is right to argue that the US must first choose its goals for space and then choose the means for meeting those goals. But the US space programme is today suffering from what might be called schizophrenia. And the civilian/military demarcation line is no longer very clear. The US space programme is required to contribute to American scientific and technological leadership, take the "high ground" for the military, promote the commercial exploitation of space and, yes, foster international cooperation. Furthermore, we're seeing an increasing tension within various parts of the US space programme between those who wish it to devote resources to developing new programmes and those who wish to apply existing technology more widely.

Unfortunately, the US has also apparently entered a new era of austerity. Quite recently, the Soviet Union sent Vega 1 and Vega 2 up to get a closer look at Halley's comet. Giotto was launched by the European Space Agency for the same purpose. And two Japanese spacecraft approached the legendary "dirty snowball." All in all, there have been eight probes to Halley's comet – none American. A US mission was scrapped as too expensive. And with Gramm-Rudman, budgets are likely to contract even more.

Even more disturbing – and in the long run, I think,



The US National Commission on Space which reported to President Reagan in May (*Spaceflight*, May 1986, p.194) outlines an exciting series of goals which include the establishing of manned settlements on the Moon and Mars by the years 2017 and 2027 respectively.

International cooperation could help America realise such goals more quickly and less expensively, according to a section of the report entitled International Co-operation and Competition. It states: "For a few projects of lasting significance, we believe that the United States should lead coalitions of participating nations, as it did with INTELSAT and is now doing with the Space Station."

The report says that a good example of a possible cooperative project is the coordinated robotic exploration of Mars and that, on a more ambitious scale, it has been suggested the United States send an automated surface rover as part of a joint Mars mission while the Soviet Union sends a lander capable of returning samplesof Martian material to Earth.

An early manned base on Mars is depicted above by artist *Julian Baum* and shows a high wing span glider being used as an economical means of transport through the low density Martian atmosphere. A Mars settlement in the 21st Century is depicted on the right by artist *Robert McCall* and in the distance shows a spacecraft departing the Martian base.

more damaging – is a perceived tendency on the part of the US toward unilateral programmes and actions, and a concomitant withdrawal from multilateral cooperation. For example, when the United States allowed its space cooperation agreement with the Soviet Union to lapse in 1982, who was really hurt? Many politicians and commentators have argued that the agreements inordinately benefited the Soviet Union by transferring superior US technology to the Soviets. The truth is somewhat different, as Senator Matsunaga's new book 'The Mars Project' points out. Unfortunately, few people outside the scientific community seem to realise how valuable that cooperation was for American scientists. Between 1971 and 1973, to take just one example, the Soviets launched four missions to Mars, in each case with limited success. But they obtained an immense amount of operational data during those missions, especially on choosing launding sites and on the problems their spacecraft encountered during descents to Mars' surface. The Soviets made that information available to the US and it helped considerably in designing the subsequent Viking missions to Mars. The US was able to learn much from Soviet experience. Whose interests does it serve then, to abandon a vehicle for cooperation?

Of course, despite any seeming loss of direction or belt tightening, despite any self-imposed isolation, the US space programme can still lead the world. But the rest of the world is catching up.

The Rest of the World is Catching Up

The People's Republic of China has this year announced plans for its first commercial space venture, the launching of a Swedish communications satellite called Mailstar (***Spaceflight***, April 1986, P.164). Reportedly, the Chinese are also negotiating with Western Union to launch one of the company's new satellites. The price – reported in the press to be just four million dollars – is about a third of what Ariane or NASA might charge, and the Chinese are offering launch insurance, which is virtually unobtainable here, for an additional ten percent. Of course, we're talking about relatively small payloads. However, China continues its work on developing new and more powerful launchers in its 'Long March' series.

Meanwhile the Soviet Union is continuing its extremely ambitious space programme. As America's space budget contracts by many accounts, the Soviet budget expands. The Salyut programme, for example, has put increasingly sophisticated manned space stations into orbit since 1971. And the Soviets have made clear their interest in manned missions to Mars. On the commercial front, the Soviets have offered to make their Proton booster available to Inmarsat; are mounting a campaign to enlarge membership in and use of Intersputnik; and some observers expect Soviet offers to expand.

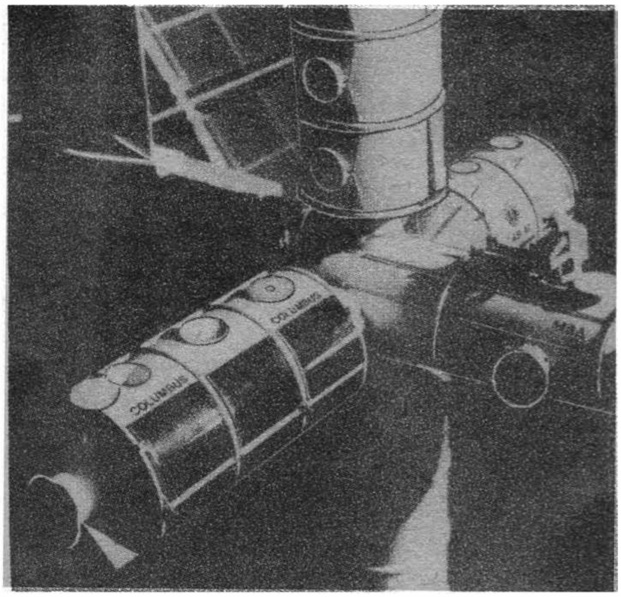
The Japanese established what is now called the National Space Development Agency in 1964, and became only the fourth country to launch a satellite in 1970. Today, Japan appears willing to spend a great deal of money to develop future generations of sophisticated communications satellites. Also on the drawing board are more advanced meteorological and remote-sensing satellites. And Japan is developing its own launcher technology, ending reliance on the 'N' launch vehicle, manufactured under licence from McDonnell-Douglas.

The Western European space programme is booming. Even with a staff and budget dwarfed by NASA's (ESA's staff was approximately 1 350 and its budget $928 million in 1985) the European Space Agency has made a substantial impact, mainly by concentrating its efforts in more limited areas than have NASA or the Soviets. Perhaps ESA's greatest triumph is the development of the Ariane launch vehicle, now launched by Arianespace, which has succeeded in capturing a very significant share of the market. Indeed, over the past decade ESA has enjoyed major successes giving Europe a substantial degree of independence in space and increasingly giving the United States stiff economic and scientific competition. How did it happen?

Cooperation in Europe

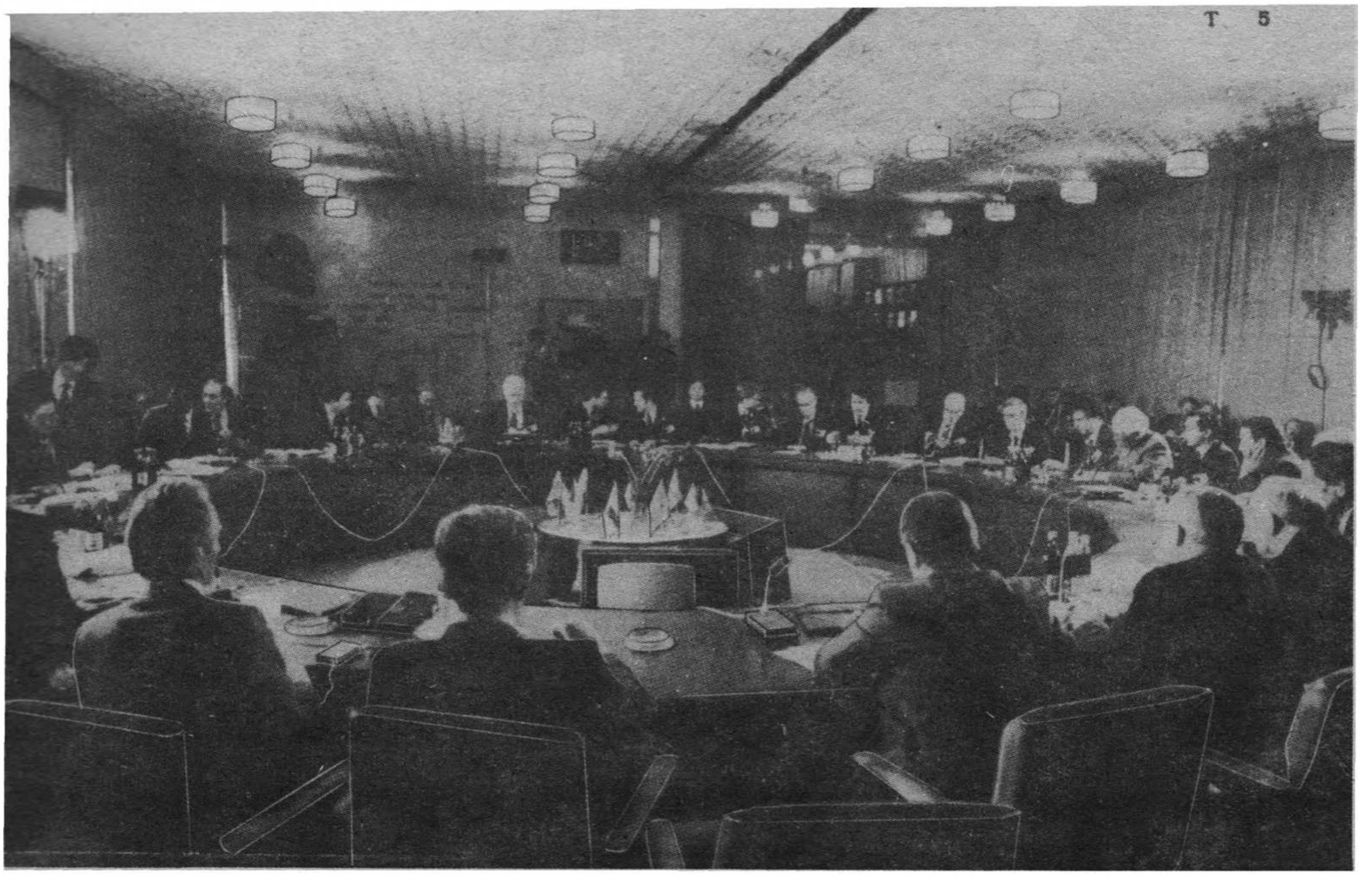
From the dawning of the Space Age most European countries realised they stood little chance of success if they opted to go it alone. In 1975 the major European powers formed ESA by combining the European Launcher Development Organisation with the European Space Research Organisation. The ESA science programme, in which all member states participate, provides a unifying core. The success of Meteosat 1 and 2 (launched in 1977 and 1981) has, for example, effectively ended European reliance on US and Soviet satellites for weather forecasting. And the Europeans are now developing their own large multipurpose communications satellites for sale to their own regional international satellite communications organisation, Eutelsat. In fact, Eutelsat recently announced that a consortium led by Aerospatiale has been awarded a contract to build up to eight communications satellites (*Spaceflight* June 1986, p.261). No American firm was in the running. Obviously, in part this was a politically imposed exclusion. Just as obviously, US firms weren't needed to do the job.

A model depicting a possible configuration of the international manned space station with the European pressurised module, Columbus, attached.



Fits and Starts in International Cooperation

ESA has also tried to promote cooperation between Europe and America. Probably the best known



Scientists and specialists from the USSR, Austria, Bulgaria, Hungary, GDR, Poland, France, FRD and Czechoslovakia at an international meeting to discuss results of the Vega project.

example of this is Spacelab. But while Spacelab has proven to be a technological success, the Europeans have voiced concerns over the programme. Although the US has fulfilled to the letter its agreement with ESA, there has apparently been some disappointment voiced in Europe that Spacelab hasn't been used more often, or that more units have not been purchased by NASA to help amortize development costs.

Similarly, while ESA, Japan and Canada have signed agreements with the US to take part in the preliminary definition and design of the proposed NASA Space Station, no one seems to agree on how the work should proceed. Clear leadership is still needed.

As originally conceived, the Space Station will be the largest civilian engineering collaboration in history. Indeed, President Reagan, in his 1984 State of the Union Address, announced that one of the major objectives of the programme is to foster international cooperation. Mr. Reagan said, that January night, that America "... wants [its] friends to help us meet [the] challenges and share in the benefits. NASA will invite other countries to participate, so we can strengthen peace, build prosperity and expand freedom for all who share our goals."

Certainly, if international participation does materialise, non-US contributions will be significant. ESA may well spend two billion dollars or more. Japan has in mind constructing a module costing about one billion dollars, and Canada may spend up to 500 million dollars building systems that will become part of the core station. And each country will contribute valuable technical know-how to the project. How can the United States turn down an offer like that?

After all, NASA spent the better part of two decades trying to get approval for a permanent manned Space Station. NASA has called it "a way station on the road to the planets" – a staging ground, not only for "mundane" things like the launch of communications satellites, but eventually, for a trip to Mars. For the less visionary, NASA has pointed to the commercial opportunities provided by the Space Station – materials processing, drug manufacturing, you name it. So why shouldn't NASA leap at the offer of a capital infusion and technical help?

But some have questioned whether, by inviting Japan, Canada and Europe to participate, the US is not undercutting itself. After all, its collaborators in the Space Station may also become its principal competitors in Space. Is the US providing an infrastructure what will allow others to skim the economic cream of space business?

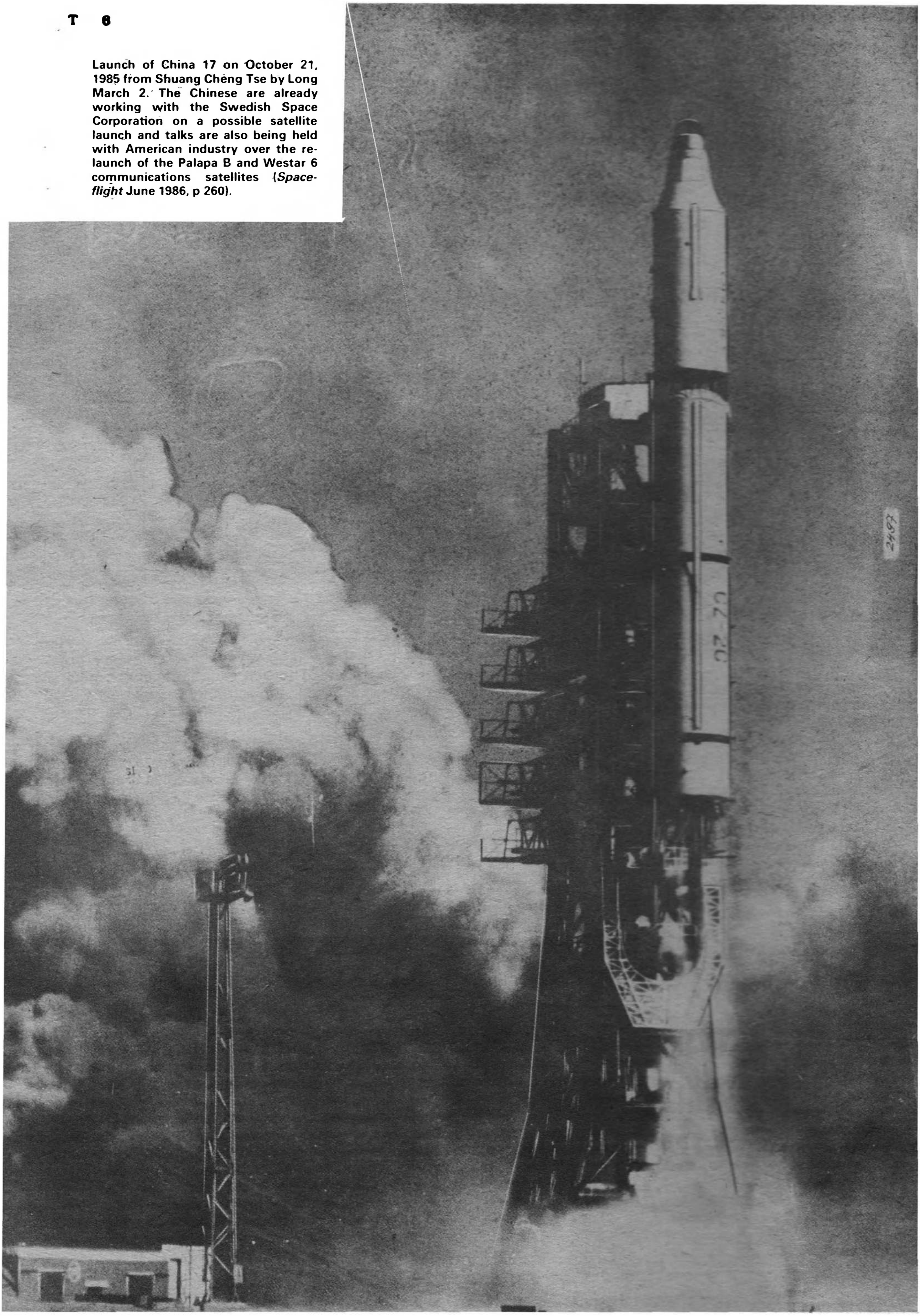
And what about other proposed Space Stations? Private companies, including Fairchild Industries and Space Industries Incorporated of Houston, have announced plans for, or are considering development of, their own independent Space Stations and platforms. Can we, as a world community afford duplicative efforts in space at this time? Are the vast sums of money required, and the tremendous risks involved, conducive to the willy-nilly, competitive development of Space?

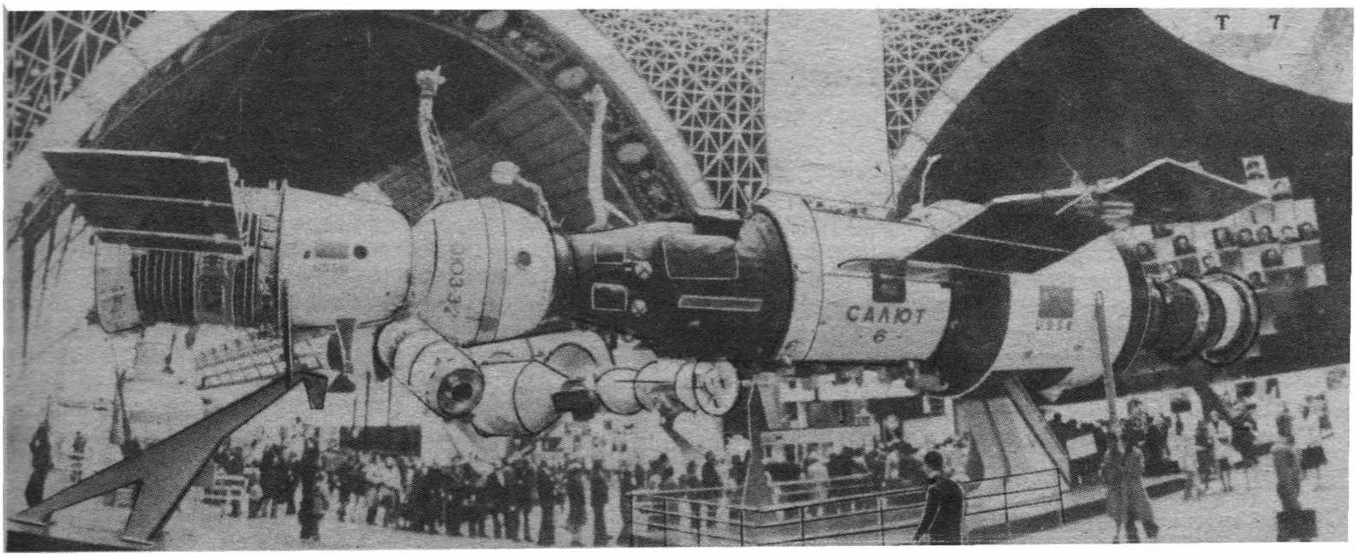
Learning from the INTELSAT Experience

There is, in my mind, a historical antecedent which may help to answer these questions. And that is the creation of INTELSAT in the mid-1960s. INTELSAT was formed as a result of a US initiative. The United States understood that, in order to provide truly global communications satellite coverage efficiently, cooperation was critical. After all, it takes the cooperation of at least two countries to complete one international phone call. So the US was simply trying to do something collectively that could not be done as well, or as cheaply, on a national basis. The result provides an experience worth considering.

It provides for the pooling of international resour-

Launch of China 17 on October 21, 1985 from Shuang Cheng Tse by Long March 2. The Chinese are already working with the Swedish Space Corporation on a possible satellite launch and talks are also being held with American industry over the re-launch of the Palapa B and Westar 6 communications satellites (*Spaceflight* June 1986, p 260).





Cosmonauts from various countries visited the Salyut 6 space station during the early 1980s as part of international cooperation agreements. They included Pham Tuan (Vietnam) Vladimir Remek (Czechoslovakia), Georgi Ivanov (Bulgaria), Miroslaw Hermaszewski (Poland), Bertalan Farkas (Hungary), Ziegmund Jähn (the GDR), and Arnaldo Tamayo Mendez (Cuba). *Novosti*

ces. INTELSAT allows both economies of scale and joint international investment to occur. This has allowed over a hundred countries to participate directly in Space communications, with net savings and economies for all countires – big and small, developed and developing.

INTELSAT, although a non-profit cooperative, operates strictly on commercial principles. Services must be paid for. Members are required to invest capital in proportion to their use of the system. Non-payment of bills results in penalties. The INTELSAT Agreement specifies that awards ofcontractsare to be made only on the basis of the best price, best quality and best delivery schedule available, as determined under competitive conditions. INTELSAT, then, is not like the much maligned, typical international bureaucracy. Instead it is a highly motivated, dynamic organisation, with a relatively small staff.

The INTELSAT organisation has also operated a modest but targeted international R&D programme. Innovations by INTELSAT include: the first operational use of spot beam antennas; the first application of frequency re-use through beam separation; the first operational international digital satellite communications system providing service to rooftop antennas; and the first international application of micro-terminals less than one metre in diameter. INTELSAT R&D efforts alone have produced the nickel hydrogen battery; high performance low-noise filter designs; advanced SS/TDMA systems; and advanced solar cell designs. So it's clear that INTELSAT has aggressively pursued leading edge technology. And today, we are exploring the possibility of a jointly sponsored inter-satellite-link (ISL) development with ESA and Eutelsat.

And its just as clear that the creation of INTELSAT has greatly benefited the US, including its aerospace industry. International cooperation has resulted in billions of dollars of orders for US aerospace companies. But to my mind, the real value of INTELSAT has been its role in fostering global co-operation – cooperation that benefits everyone.

Cooperation is the Key

Like satellite communications two decades ago, can advanced Space technologies really be fully supported and utilised in an environment onsisting of several, or many, competing national, regional and so-called international programmes.

Most of the major initiatives in space – including many future space communications projects – will require massive financial commitments, coordinated planning, and the pooling of technical and economic resources. Why eschew multilateral cooperation, when it has worked so well in the INTELSAT and other experiences?

It would be relatively easy for me to recite a lengthy "laundry list" of ideas for the cooperative development of Space. Instead I will discuss just a few: the Space Station, launch vehicle development, and the cooperative development of an aerospace plane.

The Space Station: A Cooperative Venture

In the mid 1970s, NASA realised that the US and Soviet space programmes were proceeding on remarkably complementary lines. While the US was focusing on building a Shuttle – ideal for servicing a Space Station – the Soviets were concentrating on building a Space Station. The Soviets already had a Space Station, the Salyut, that they were interested in upgrading to a multi-pod complex.

In 1977, after talks lasting several months, the US and the USSR signed an agreement on manned space flight cooperation. The agreement specifically called for a Shuttle-Salyut programme and a Space platform programme. Under the Shuttle Salyut programme, the US Shuttle would be used to transport scientific experiments to the Salyut Space Station. Under the second, more visionary programme, the two nations agreed to jointly define the objectives of a new station, consider various designs and plans, and develop specific proposals for its implementation.

Indeed, shortly after the agreement was signed, the Soviets presented a number of specific proposals for the Space Station involving X-ray astronomy, cosmic-ray research, materials processing, biology and medicine, meteorology, radio astronomy and atmospheric research – a list remarkably similar to that proposed today for the as yet to be built US Space Station. Unfortunately, nothing of substance was accomplished – the US pulled out of the agreement in response to Soviet activities in Africa and attitudes toward internal dissidents. The possibility that the cancelled plans might have been in the long-term interest of the US may not have been given full consideration.

Whatever the facts at that time, today the US can not afford to be short-sighted. As I mentioned earlier, there are serious political obstacles to the successful

development of the Space Station. Obstacles that will not just disappear – they must be overcome by cooperation. Europe and Japan have expressed concern that their desire for autonomy is in danger of being trampled by NASA. All parties are worried about the sharing of proprietary data. Last autumn, the Europeans raised doubts about NASA's claimed need to control any vehicle coming within 20 kilometres of the Space Station. Even more serious doubts have been raised about the reliability and cost efficiency of the Shuttle system. Nor are prospective partners of the US sanguine about the stability of future US funding in the face of Gramm-Rudman-Holdings. How could they be?.

Meanwhile, the US is pursuing unwieldy government-to-government MOUs and completely ignoring other prospective partners. Why doesn't the US consider a true multilateral approach to designing, developing and funding of Space Station with Europe and Japan, if not the USSR or China? While it's true that dozens and perhaps hundreds of nations, corporations and other groups are expected to participate in the programme for short periods of time, to meet specific requirements, they must be distinguished from the partners. Are there ideological reasons, or is a concern over stifling America's corporate exploitation of space, or even losing a competitive advantage in space technology, inhibiting international cooperation? Can US businesses, with little or no government assistance, fully exploit the opportunities that abound in Space? Business is cautious. Few businesses, other than the communications industry, seem willing, as yet, to commit big money to ventures in space. And it will take very, very large sums of money, and many years, to get a commercial payback from most Space activities. Unfortunately, that is rather unappealing to modern American corporations whose horizons are often limited to three, four or five years.

The Space Station (which the recent report by the Business-Higher Education Forum called "the centerpiece of America's Space infrastructure") is too important to the future of the US – and the world – to let languish amid arguments and debates. By expanding the Space Station partnership, the project will not languish. The United States can use the development of the Space Station to expand its leadership in Space, by promoting multilateral cooperation. Or it can retreat and find itself increasingly isolated by a rapidly advancing world.

Expendable Launch Vehicle Development

Many organisations resented what appeared to be the abandonment of programmes, such as the Atlas-Centaur programme, in order to promote the Shuttle. Yet, the world – and INTELSAT – are very much in need of a relatively inexpensive, expendable launch vehicle. Why not develop such a vehicle through multilateral cooperation? Of course, NASA offers its services to the international market place, and achieves economies of scale by doing so. And, as I mentioned earlier, there are many new entrants in the field. But why not look out to the future, to follow-on programmes designed to capture the advantages of international cost sharing, technological cooperation and joint risk taking? NASA's Ivan Bekey has argued that the world must develop a vehicle that can deliver a kilogram to low-Earth orbit for five to ten dollars, to geosynchronous orbit for ten to 20 dollars, and to the Moon for 50 dollars. The market is clearly there. Even at today's prices, experts at Battelle's Columbus Laboratories have predicted that as many as [illegible] payloads may be launched into space before the end of this century.

A US policy to encourage the private, competitive development of expendable launch vehicles raises the following question: can US firms compete with foreign governments eager to capture launch business, and so subsidise the development of a key industry?

On a similar note, it makes little sense to me that an inter-agency federal task force, according to a recent report in the *Wall Street Journal*, may be about to recommend that NASA abandon the launching of private commercial and foreign satellites. Turning NASA into the private servicing arm of the Defence Department will be a costly step backward for the United States. Shouldn't NASA be expanding its customer base?

Cooperative Development of an Aerospace Vehicle

On a related matter, a growing number of experts are arguing that new technologies are coming together with existing technologies to produce the possibility of a new way to enter space: an aerospace plane. They foresee a vehicle able to operate with equal ease and efficiency in both the atmosphere and space. Most important, they see a massive decrease – perhaps tenfold – in the costs of launching objects into low-Earth orbit. Of course, that's what Shuttle proponents argued back in the late 1960s and early 1970s.

At that time, Saturn boosters were delivering Moon-bound payloads to low-Earth orbit for slightly less than $1,500 per kilogram. NASA argued that they could deliver cost-to-orbit for as little as $[illegible] per kilogram with the Shuttle. Unfortunately, today it costs about $3,100 to deliver by Shuttle one kilogram into low-Earth orbit. Even considering inflation, that's a staggering difference. Of course, that's just to get a satellite into low-Earth orbit. It takes a lot more equipment, and a lot more money, to boost satellites from low-Earth to geosynchronous orbit.

Perhaps the trick will be to develop vehicles that can be manned or unmanned according to need. Certainly, there is no need for a human presence during satellite launches, for example. So why build in costly human support systems?

Either way, an aerospace vehicle – preferably one that can carry people or not – may be best to develop through cooperation rather than competition. Why? The reasons aren't very mysterious. Given the leading-edge technology involved, the enormous capital required, and the huge risk, having many partners, each with ready access to resources, makes the most sense. Once developed, the [illegible] launch vehicle system should be operated on commercial principles.

For many thousands of years, man has flown through space by way of myths, legends and poetry. Today, we are at the dawn of a new era. But as we have actually launched ourselves into outer space, we have discovered that it is, to a large extent, a limited resource. We are constrained economically and politically. To exploit space efficiently, we must work together. Technology is not in question. The only real question is: do we have the vision to cooperatively embark into the universe in order to truly benefit humanity?

This article is based on a statement to the American Institute of Aeronautics and Astronautics given by [illegible], Director-General and Chief Executive of INTELSAT, on April [illegible].

SOVIET SPACE COOPERATION

by Valdimir Shatalov

Soviet space science has advanced by leaps and bounds since Yuri Gagarin's pioneering flight 25 years ago. A high-capacity space research and development industry has been created, communications and weather research space systems are effectively operating, as are navigational, natural research and other satellite-based systems geared to practical needs. Many of these activities have now been carried out jointly with other countries over a number of years.

Near Earth and outer space are being probed with both manned craft and automatic interplanetary stations. In all, more than two thousand space vehicles for research and commercial missions have been put into orbit since the space era began.

The operation of orbital stations, in particular sustained expeditions, are among the Soviet Union's most important achievements. The Salyut-7 has set a so far unbroken record of 237-day space mission. Soviet space science has, in fact, about a dozen expeditions that have lasted for months to its credit.

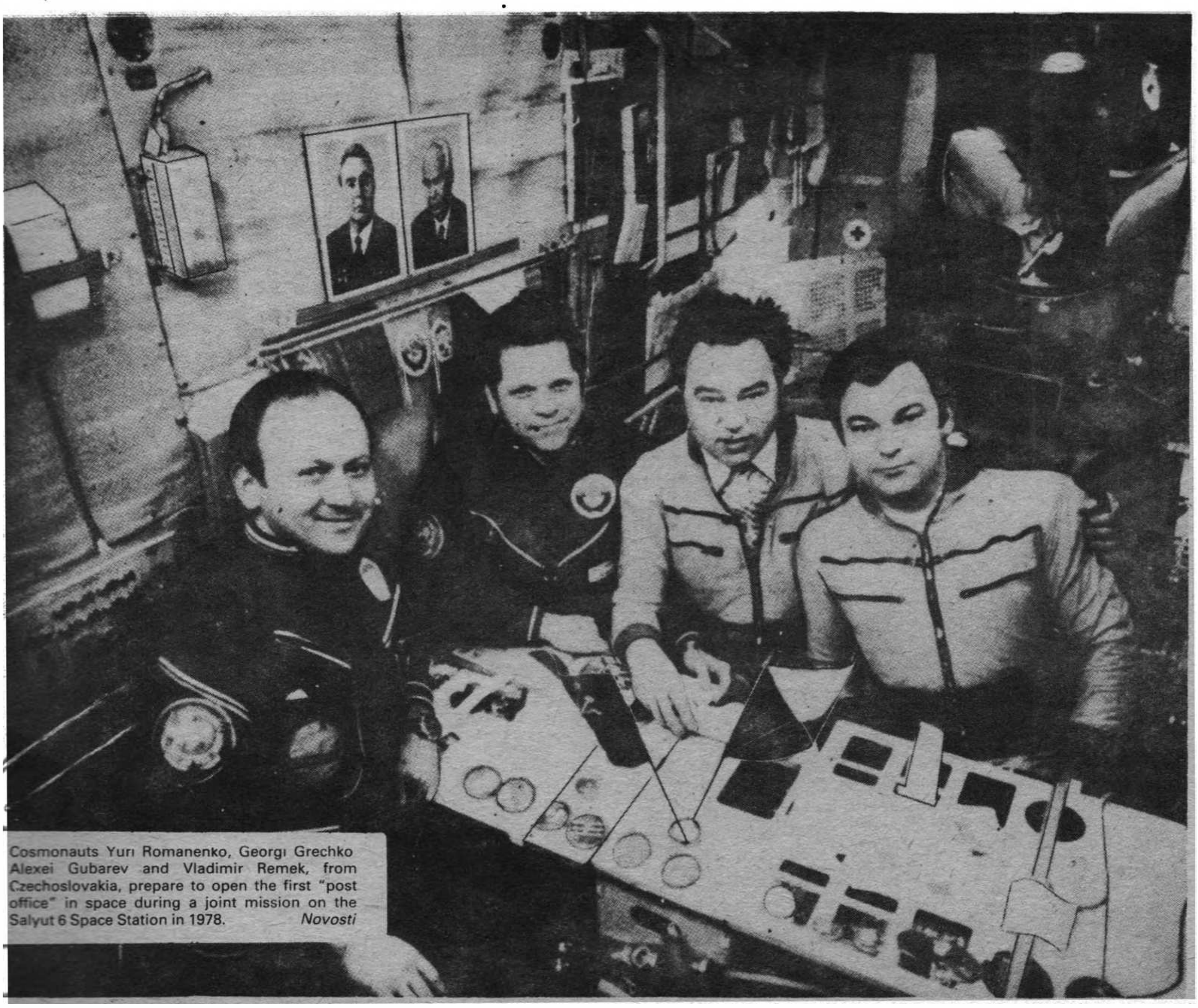
Such expeditions have not, of course, been an end in themselves, nor meant as record-breaking performances. A vital objective has been to establish an optimal time for a cosmonaut to live and work in orbit to maximum advantage.

Sixty Soviet spacemen have orbited the Earth, many more than once. Leonid Kizim and Vladimir Solovyov settled aboard a new, Mir (Peace) orbital station in April. It is Kizim's third flight and Solovyov's second.

Nine representtives of socialist countries involved in the Intercosmos programme, and others from France and India, have joined Soviet spacemen in orbit. Preparations are under way at Stellar Town, not far from Moscow, for a Soviet-Syrian space mission. Agreement has been reached on a French spaceman joining a sustained Soviet space mission in 1988.

Second-generation orbital stations have made a great contribution to the development of space technology, nature research, medicine, biology, astronomy and other sciences. The scores of thousands of pictures they have sent back to Earth, and the many samples of materials – semi-conductors, optical glass, medical and biological preparations – have been used not only for research but also for practical purposes. The Salyut-6 was in space for nearly five years, almost half that time as a manned vehicle. In 1982 its mission was taken over by Salyut-7.

Right now we are beginning to develop a



Cosmonauts Yuri Romanenko, Georgi Grechko Alexei Gubarev and Vladimir Remek, from Czechoslovakia, prepare to open the first "post office" in space during a joint mission on the Salyut 6 Space Station in 1978. *Novosti*

permanently operating obrital complex – a Mir station with six docking ports as its basic unit. This third-generation station is a major advance not only in Soviet but in world space science. It is the first of its kind to have docking facilities for entire ground-built research laboratories and workshops. This will make for broader international cooperations in space as the modules will be able to carry quite sizeable instruments made by other countries.

The Mir station has the greatest-ever extent of automatic control, increased solar battery capacity, and better facilities for work and relaxation, which is of considerable importance, above all for sustained missions.

The amount of space work grows from year to year. The Mir station can be seen as the space science of today, perhaps of tomorrow. But what next? There have been some suggestions in the press that stations designed to carry a hundred people and more may well be built before long. It must be clearly understood that to put so huge a complex into space would involve formidable difficulties. A station with a mass of a thousand tonnes would require a giant rocket with a starting mass of hundreds of thousands or even a million tonnes to launch. That is clearly a prohibitive proposition.

The Mir type of complex seems more promising, making it possible in principle to assemble in space objects of any size and any purpose: research labs and factories, environmental monitoring devices or means of illuminating the Polar regions in winter time with reflected sunlight. Generally speaking, although there should be no oversimplification here, such an approach could be applicable to the creation of entire space settlements of the "ethereal cities" Konstantin Tsiolkovsky, father of Soviet rocketry, once wrote about.

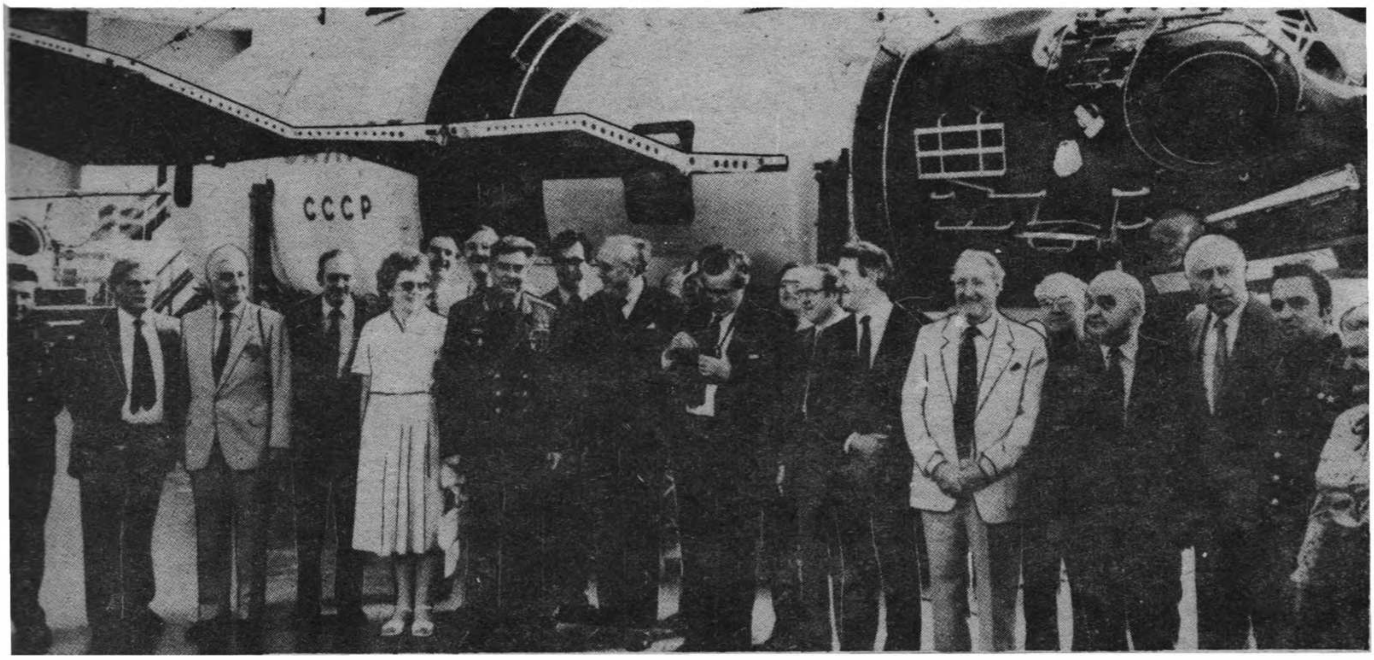
A similar method of assembly could eventually be used to set up orbital spaceports for manned interplanetary craft needing to be fitted out for voyages. Not a prospect for the foreseeable future, but science and technology are, after all, developing at an incredible rate. I am sure that the day will come when man will begin to colonise the Moon, Mars, or the asteroids. For the time being automatic vehicles are paving the way to planets and other celestial bodies.

We have recently been rejoicing at the spectacular success of the Vega station which formed part of the international "Venus-Halley's Comet" project. The object of exploration in the first stage was Venus, and in the second the legendary and mysterious cosmic wanderer. It is encouraging that Halley's comet has been studied under a wide-scale international programme. I refer to the cooperation of scientists not only within the framework of the Vega project but also with experts engaged in West European and Japanese projects.

The Soviet Union has put forward another equally interesting idea which is already being put into effect under a wide-ranging international programme. The project is to make a full study of Mars and its natural satellites (***Spaceflight,*** March 1986, p113). Automatic stations for that expedition will be designed and constructed by the Soviet Union, and instrumentation for them will be produced by ten countries in all: six socialist and four West European.

The Intercosmos programme shows that international cooperation can be effective not only in the field of pure research but also in actual practice – witness the COSPAS-SARSAT system, originally created by the USSR, the US, France and Canada, and now involving about a dozen nations. Everybody understands quite well that there could be far more cases like this.

Stress was laid at the 27th Congress of the CPSU that science and technology in our times provide a good opportunity to ensure a life of plenty on Earth and to create the material conditions for social prosperity and individual progress. That must be the aim for science and technology, including space science.



A delegation of UK Parliamentarians, headed by Lord Whitelaw the Deputy Prime Minister, visit the Yuri Gagarin Cosmonaut Training Centre on May 24, 1986.
Novosti

Soviet Space Offer to Britain

The visit of a British parliamentary group to the USSR in May has been followed by a letter to the Trade and Industry Minister, Mr. Geoffrey Pattie, asking him to consider an offer for British astronauts to join Soviet space missions.

During its tour in the USSR, the British delegation visited the Yuri Gagarin Cosmonaut Training Centre to hear about the extent of the Soviet manned space flight programme and the involvement in it of non-Russian cosmonauts, including East Germans, Czechs, an Indian and a Cuban. This was followed by a suggestion to the delegation from General Georgy Beregovoy, head of the space programme, that Britons might one day join them.

The proposal was repeated by the General two days later at a Kremlin dinner and the delegation asked to pass it on to the UK Government.

Several important factors are involved in the new proposal. Britain has traditionally valued and participated in international collaborative space programmes and with the establishment in November 1985 of the British National Space Centre is now better organised to handle the complex management of such operations. Over many years scientific programmes with NASA and within ESA have provided the main opportunities for British space scientists. Likewise, the main benefits from space applications to such every-day services as communications and weather forecasting also stem from international collaboration. The initial assessment of a joint Anglo-Soviet space programme could, therefore, be one of significance to Britain in terms of both unmanned and manned projects.

The timing of the proposal is also a factor, coinciding with the recent incidence of launch failures which have seriously reduced the West's satellite launching capability and disrupted future planning. In particular, June 24 was to have been the date when Britain's first astronaut was launched into space and these hopes have now been delayed for at least two years by the Shuttle disaster. The offer of new launch opportunities in conjunction with a space programme as extensive as the Soviet one therefore warrants examination.

As with any joint enterprise, success depends very much on having clearly evaluated objectives. A recent example in the area of unmanned space flight has been that of the Giotto probe to Halley's comet. With manned space flight the objectives of the mission call for still greater in-depth consideration in view of the higher costs and complexity involved.

Also, there are technological factors that come into consideration involving both compatibility of users' equipment and a required high level of communication and exchange of information. Given adequate time and preparation such requirements would be met in any international enterprise but the effect of such difficulties in terms of time and cost for a joint Anglo-Soviet programme needs to be balanced against similar considerations in other international arrangements.

A further factor is the part that acceptance of the Soviet offer (in terms of an otherwise well-evaluated proposal) would play as a propaganda ploy. The answer here probably depends on the nature of the joint mission and its timing, so that existing plans with the US, which are at present subject to uncertainty and delay, are not compromised.

France has for many years carried out joint space projects with the Soviet Union, including manned flights, while maintaining Western allegiances; and the UK already participates in scientific and other cultural exchanges with the USSR. Clearly the possibility should be explored of finding an acceptable UK stance. On the other hand, if on further examination the invitation is primarily motivated by its propaganda and public relations value, it clearly must be treated as such.

Coment

UP-DATE USA

SHUTTLE INQUIRY – Commission Urges Major Changes

The resumption of Space Shuttle flights following the Challenger disaster on January 28 now seems unlikely to occur before the end of 1987 at the earliest.

Publication of the Presidential Commission Inquiry report on June 9 after four months of intensive investigations has confirmed a far-reaching series of measures, both technical and managerial, for NASA to take onboard.

The Commission, appointed by President Ronald Reagan immediately after the disaster, was chaired by William Rogers, a former Secretary of State under Richard Nixon, and consisted of 14 astronauts, scientists and engineers.

It blamed the disaster on the rupture in a lower joint of the Shuttle's right Solid Rocket Booster (SRB). When Challenger was launched temperatures were 15 degrees lower than on any previous launch and the report concludes that this abnormal cold was a contributing factor.

Calling for a new joint design that would enable it to withstand many of the stresses that led to the leakage of hot gases and subsequent explosion, the Commission recommends creation of an independent committee purely to oversee the design and testing of the joint.

The main recommendations in the 256 page report are:

- Redesign of the booster joint.
- Establishment of a NASA safety office and independent review boards.
- Improved communications within NASA and the industry.
- A study of crew escape systems.
- Improved safety margins on tyres, brakes and steering.

The Commission also called for a fundamental change in the US space programme, namely to move away from the almost total reliance on a single launch system.

"Reliance on the Shuttle as a principal launch capability created a relentless pressure on NASA to increase the flight rate. Such reliance on a single launch capability should be avoided in the future," said the report.

The Commission says that the SRB manufacturer, Morton Thiokol, has failed to heed a history of deep concern about the safety of the O-ring seals in the SRB joints.

Serious weaknesses in NASA management structures and quality control were blamed as further contributing to the accident and the report stated: "The Commission concluded that there was a serious flaw in the decision-making process leading up to the launch."

It continued that even the most cursory examination of the O-ring failure rate on previous missions should have indicated that a potentially serious situation was developing.

The report states that the decision to launch was based on "incomplete and sometimes misleading information, a conflict between engineering data and management judgements and a NASA management structure that permitted internal flight safety problems to by-pass key Shuttle managers."

Referring to the eve of launch discussion between engineers at NASA's Marshall Center and those at Morton Thiokol's factory in Utah over whether it was too cold to launch, the Commission blamed both NASA and Morton Thiokol for overriding the engineering concerns and recommending a launch. The report said word of the crucial discussion had not been passed on to the high-ranking NASA officials who had final authority to recommend launching.

The space agency has been told to report in 12 months time on the progress being made, an indication in itself that there will be no quick fix-it before the Shuttle flies again.

Presidential Commission members during the 51L investigation. From (from left): Neil Armstrong (vice-chairman) and William Rogers (chairman). Back (from left): Joseph Sutter, Robert Rummel and Major General Donald Kutyna.

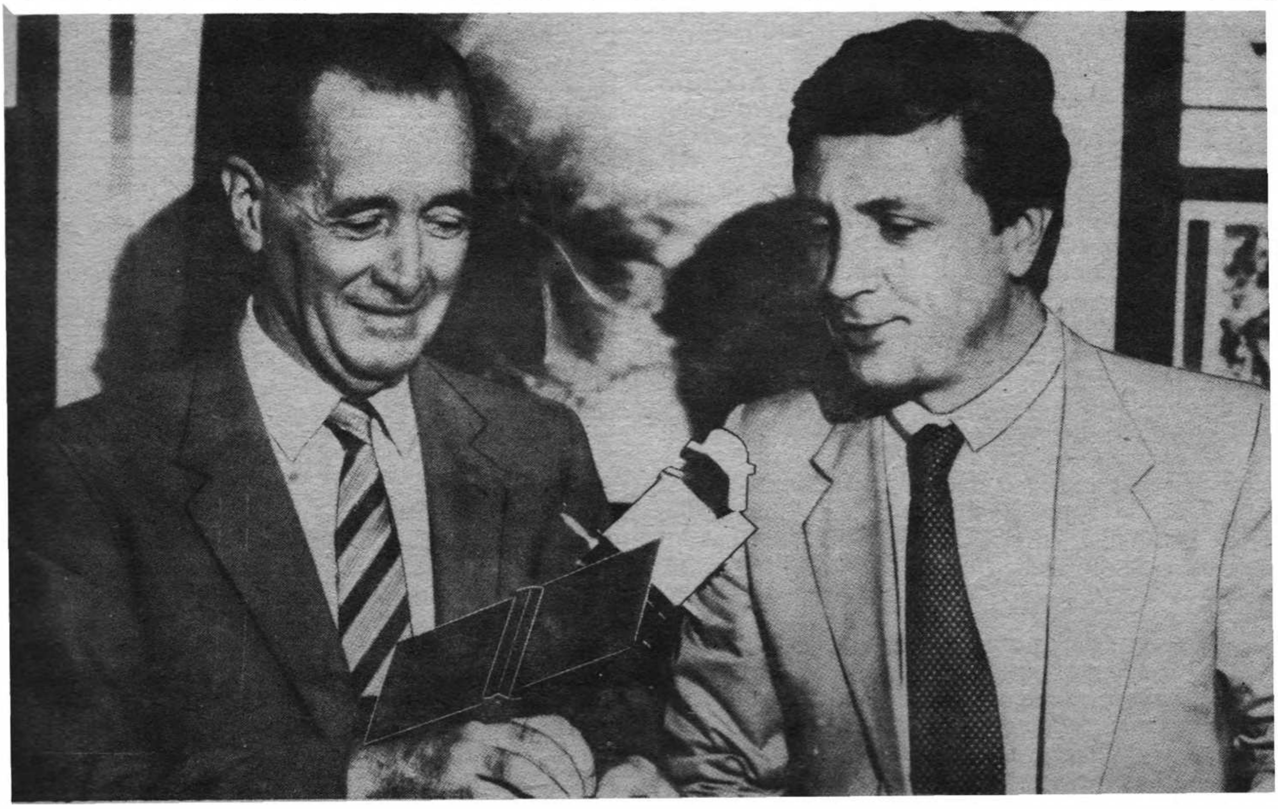
SHUTTLE EVENTS

Spaceflight has provided extensive coverage of the events subsequent to the Shuttle disaster including the inquiry and various relevant aspects of the programme. The following is a summary of the main articles of interest:

72 Seconds to Disaster, March 1986, p.[illegible]
Flight Record, March 1986, p.102
Planning for an Emergency, March 1986, p.[illegible]
Kennedy Space Center Landings, March 1986, p.[illegible]
Solid Rocket Boosters, March 1986, p.[illegible]
External Tank, March, p.109
Nose Wheel Steering, March 1986, p.[illegible]
Divers Find Challenger Cabin, April 1986, p.[illegible]
New Orbiter Needed, April 1986, p.[illegible]
Young Critical of Launching, April 1986, p.[illegible]
Notebook from the Cape, April 1986, p.[illegible]
NASA Sets Budget for 1987, May 1986, p.[illegible]
Inquiry Hears of Booster Concerns, May 1986, p.[illegible]
Commission Set to Report, June 1986, p.[illegible]
Astronauts Unaware of Joint Problems, June 1986, p.[illegible]
KSC Landings and Attempts, June 1986, p.[illegible]

A complete set of ***Spaceflight*** *issues for 1986 is available by subscription to the British Interplanetary Society (see form on inside front cover). Individual back issues are also available for £2.00 (post free) from the Society.*

EUROPEAN RENDEZVOUS



Roy Gibson (left) and Dr Gerard Brachet examine a model of the Spot 1 Satellite after signing a contract for distribution of Spot data in the UK by the National Remote Sensing Centre.

UK SPOT CONTRACT

A contract that will enable the National Remote Sensing Centre at Farnborough to distribute in the UK data from the Spot 1 remote sensing satellite was signed on June 9 by Roy Gibson, Director General, British National Space Centre.

The Spot satellite, launched in February 1986, heralds a new era in remote sensing as it incorporates a number of novel features, including high resolution imagery and the capability to offer stereoscopic pairs of images of any given area.

The main applications of Spot data are expected to be in the areas of mineral exploration, agriculture, forestry, water resources and cartographic work (***Spaceflight***, June 1986, p.257).

The contract was signed between Mr Gibson and Dr Gerard Brachet, President of Spot Image, the French commercial company which manages the Spot programme.

"In the past 15 years an enormous amount of data has been received from remote sensing satellites and this is becoming increasingly important to a wide range of industries. The signing of this contract will enable the NRSC, whose work is predominantly user-orientated and includes the supply of remotely sensed data and imagery, to be better able to assist the growing community of British users both in Universities and the private sector," said Mr Gibson.

Spot 1 has a payload of two identical high resolution visible (HRV) imaging instruments, which operate in either of two modes – black and white with a ground resolution of about 10 metres or multi-spectral (three separate spectral bands which can be combined to generate colour imagery) with a ground resolution of 20 metres in the visible and near infra-red parts of the spectrum.

The aim of the National Remote Sensing Centre is to introduce new users to satellite imagery and to demonstrate how the data can be used for a variety of applications. NRSC is now the second distributor in the UK for the high resolution Spot pictures. The other is Nigel Press Associates, remote sensing consultants, based at Edenbridge in Kent.

REVIEW

Space Shuttle

G. Torres, Arms & Armour Press Ltd., 2-6 Hampstead High Street, London NW3 1QQ. 134pp, 1985, £6.95.

This is an excellent well-produced little book which, sub-titled "A Quantum Leap", sets out the story of the Shuttle from the first steps to the far future, with the Shuttle acting as carrier for planetary payloads. It is extremely well presented, easy to read and enlivened with numerous illustrations.

The text, while not overlong, is concise, informative and yet eminently readable. Those wishing to know more about the Shuttle for the first time will find this book ideal.

EUROPEAN RENDEZVOUS

ARIANE INQUIRY TO REPORT

An initial report into the loss of Ariane V18 was due to be completed at the beginning of this month (July), just one month after the ill-fated launch.

Early analyses confirmed that the Ariane 2 launch vehicle behaved normally until the second/third stage separation four minutes and 36 seconds after lift-off on May 30.

First findings reported by engineers suggested that all the commands sent by the on-board computers were received by the actuation devices but that thethird stage engine ignition and start-up phase ceased abruptly.

This launch was the first of the Ariane 2 version of the launcher, which is the same as Ariane 3 but without the strap-on solid rocket boosters. Payload was the telecommunications satellite INTELSTAT V F14 which would have been placed into geostationary orbit and had a capacity of carrying 15,000 simultaneous telephone calls and two colour television channels.

The failure is the latest in a series to beset the rocket's third stage. The last failure of an Ariane was on September 12, 1985 when the V15 mission carrying the Spacenet F-3 and ECS-3 satellites was aborted minutes after lift-off.

On that occasion the Ariane 3's third stage did not ignite properly and ground contollers had to destroy the vehicle as it veered of course.

Prior to that in September 1982 a third stage shut down midway though its planned burn due to damage in the turbopump gearing. Of the 18 Ariane launches so far there have been four failures.

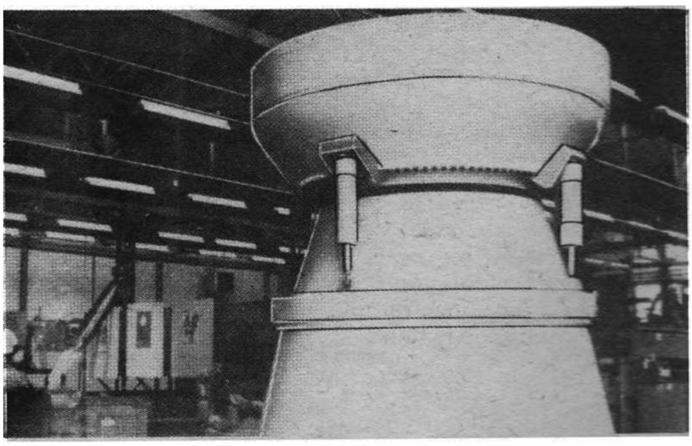
Meanwhile, Arianespace has also announced the signing of a contract for the first domestic launch of a Japanese commercial communications satellite.

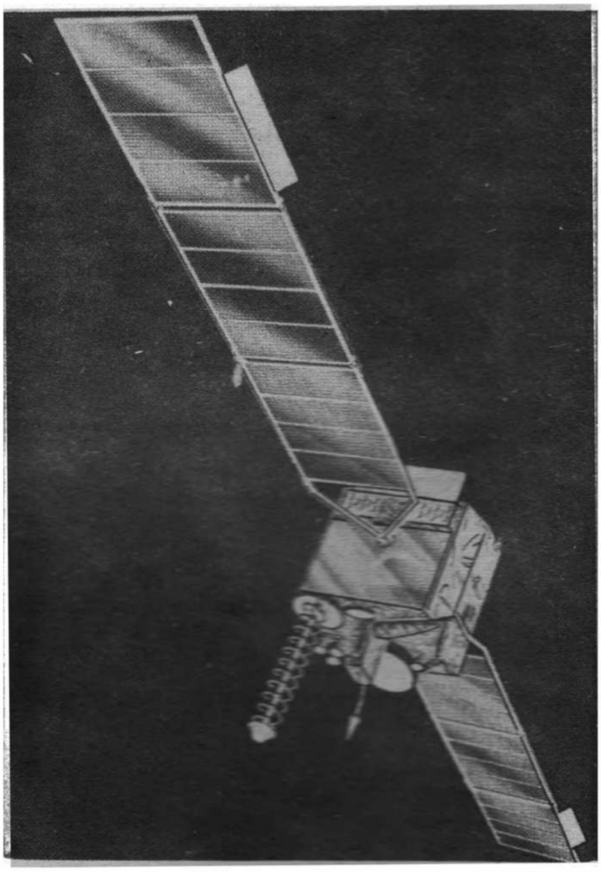
JC SAT 1 is scheduled to be launched in February 1988 on an Ariane 4, the most powerful version of the European expendable launcher, from the new launch site ELA 2 of the Guiana Space Center in Kourou, French Guiana. JC SAT 1 is the first of the new generation of heavy satellites developed by Hughes Aircraft Company. Its mass at lift-off is 2280 kg :5030 lbs).

In addition, Arianespace is to launch the Japanese communications satellites SCS-1a and SES-1b.

The "Superbirds" are the first of the new generation of satellites built by Ford Aerospace Communications Corporation and will also be launched by Ariane 4's from ELA-1.

Scale model of the aft assembly of the Ariane 5 solid rocket booster at the Societe Europeene de Propulsion (SEP) factory, Paris.





An artists impression of Br[illegible] the first of which is now likely to be launched [illegible]

HERMES ROBOTIC A[illegible]

Matra, one of France's [illegible] companies, has announced plans to [illegible] robotics remote manipulator arm [illegible] part of the country's Hermes mini-s[illegible] arm will be between six and eight metres [illegible]

YEMEN SUCCESS F[illegible]ARCONI

Marconi Radar Systems [illegible] new 13m C Band antenna at the Ye[illegible]lic's Earth station terminal for use [illegible]sat satellite communications network. [illegible] was installed and operational within a s[illegible] the inauguration of the terminal [illegible] National Day celebrations, *writes Nicholas [illegible]*

BNSC DIRECTOR

Jeffrey Fellows has bee[illegible] first Director of Projects and Techno[illegible]tish National Space Centre (BNSC).

He will be responsi[illegible] other things, developing and promot[illegible]atives of high technical and scientif[illegible] within the framework of ESA or bi[illegible]

Director of Policy and [illegible] for the BNSC, Mr Jack Leeming, was app[illegible] the year. Both report to Mr Roy Gibso[illegible]eral.

EUROPEAN RENDEZVOUS

UK's COLUMBUS ROLE

The UK will need a significant role in the total Columbus Space Station programme if it is to obtain substantial government funding for participation.

According to Mr. Roy Gibson, Director-General of the British National Space Centre, the UK will want to be involved in all aspects, including the manned module, robotics, crew interface and communications technology.

Speaking at the British Interplanetary Society Space Station Symposium in London on May 21, Mr. Gibson said the view that the UK was soley interested in a polar orbiting platform as its part of the project was untrue.

"From a political point of view the government is not interested in just a polar orbiting platform. We are talking about a 15 per cent contribution to the whole programme if we can reach satisfactory agreements."

Mr. Gibson stated that the UK would be looking for prime contractorship of the polar platform and was prepared to spend 60 per cent of its budget on this.

However, he stressed that the remaining 40 per cent would be used to ensure the UK played a major role in the other Columbus elements.

Mr. Gibson also said that he hoped the Columbus programme would be managed effectively by the European Space Agency and not dominated by "a healthy member state".

"The Space Station is not a programme on its own. It is going to influence many other activities. If we have it under some kind of 'national' control it will seriously effect what we can do in the future," he stated.

SKYNET SWITCHED FROM SHUTTLE

The first British astronaut, Sqn. Leader Nigel Wood, is now unlikely to fly in space until the spring of 1988 at the earliest.

Sqn. Leader Wood was to have flown on the Space Shuttle this month (July) as payload specialist to supervise the launch of the military communications satellite Skynet 4A.

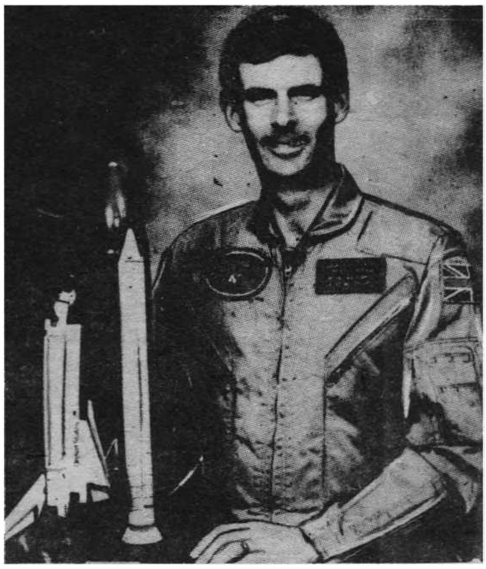
But the Challenger accident in January and subsequent grounding of the Shuttle for an indefinite period caused the UK Ministery of Defence (MoD) to re-think its schedule for the launch of three satellites.

Skynet 4A was to have been followed by another Shuttle-launched Skynet satellite in 1987, giving the UK its second astronaut. However, at the end of May the MoD announced that it had switched the launch of Skynet 4B from the Shuttle to Ariane.

A brief statement said: "The MoD has decided that the Skynet 4B satellite will be launched in late 1987 by the European-built Ariane rocket. The following launch of Skynet 4A will be by the Shuttle and take place in 1988. It has already been announced that a third satellite, Skynet 4C, is to be launched by Ariane in 1989.

"The new launch schedule follows a full review of alternatives. Arianespace offered a firm launch period for Skynet 4B some months earlier than current information indicates could have been achieved with the Shuttle.

"The UK is a member of ESA, which supports the



Sqdn. Leader Nigel Wood who will now have to wait until the spring of 1988 at the earliest for his flight on the Shuttle as payload specialist for Skynet 4A.

Ariane programme, and UK industry contributes to Ariane. The Ministry therefore particularly welcomes the availability of this competitive European system. The Shuttle also remains a competitive option in which the Ministry has confidence, as demonstrated by its choice for Skynet 4A."

The four UK astronauts, Sqn. Leader Wood, Lt.Col. Richard Farrimond, Cdr. Peter Longhurst and Mr. Peter Holmes, have now been re-assigned to normal duties. Sqn. Leader Wood will resume training for his flight in late 1987.

Skynet 4B will be put into a geostationary transfer orbit by an Ariane 3 equipped with the Ariane Dual Launch System (SYLDA).

The Skynet 4 satellites are designed to give the UK Armed Forces assured and nationally-owned satellite communications into the 1990's. The satellites, which are being built by British Aerospace with Marconi Space Systems as principal sub-contractor, will be positioned in geostationary orbit over the equator.

X-RAY EXPERIMENT FOR MIR

A joint West European and Soviet astronomical X-ray apparatus is scheduled to be deployed at the new Mir space station launched in February 1986 by the Soviet Union, ***writes Joel Powell.***

Designated "Rentgen" by the Soviets and HEXE (High Energy X-ray Experiment) by the Europeans, the device will capture X-rays from supernova remnants, X-ray stars in our own galaxy and from the nuclei of other nearby galaxies.

The HEXE working group includes the West German Max Planck Institute, Universities of Utrecht (Netherlands), Tubingen and Birmingham (UK) as well as representatives from ESA. HEXE was originally scheduled to be deployed from Salyut 7 during unoccupied portions of Salyut's mission, but delays in fabrication postponed deployment until late 1986, probably in conjunction with a STAR module.

SOVIET SCENE

Busy Schedule for Cosmonauts

Cosmonauts Leonid Kizim and Vladimir Solovyov have been very active since transferring from Mir to Salyut 7, completing two EVA's. During the first of these they erected a 15 m truss, a prototype of large structures that will be assembled in orbit.

Part of the three hour 50 minute space walk was broadcast live on Soviet television, another new departure, displaying the increasing confidence of Soviet space directors after a series of recent successes.

TV viewers were able to see the cosmonauts remove the segments of the structure from a cylinder. These were then joined by automatic devices and the whole truss fixed to the platform on Salyut 7.

The task could be compared to that carried out by American astronauts during Shuttle mission 61B in November 1985 (***Spaceflight***, January 1986, p.52).

Emergence of Kizim and Solovyov for their second EVA of the mission on May 31 was also broadcast live on television.

A new version of the Soyuz cosmonaut transport spacecraft has also been successfully tested. Launched from Tyuaratum on May 21, the modified vehicle has upgraded computers, docking system, radio communications, emergency rescue landing parachutes. Soyuz TM was launched unmanned and docked with Mir on May 23.

The vehicle design is based on the current Soyuz craft. It has the same overall dimensions and is also designed to deliver a crew of three.

The modernised spaceship has a new, more reliable propulsion unit and a new system of communication with the Earth, which enables the crew to talk with mission controllers via a geostationary satellite. The parachute system has also been changed: it is made of lighter and stronger materials, meaning a net volume saved for the return of cargo from the orbit. The crew will now be able to bring back to Earth not 50 but almost 150 kilograms of scientific materials and instruments with up to 200 kilograms being put into orbit.

In the following section ***Neville Kidger presents his latest report on Soviet manned space activities beginning with the launch of Kizim and Solovyov.***

Soyuz T-15

At 1233 (all times GMT) on March 13, 1986 the Soviets launched **Soyuz** T-15 with two cosmonauts aboard. The spacecraft – the last of its generation to fly in space – carried Leonid Kizim and Vladimir Solovyov into a near-Earth orbit ready for docking with the new orbital station Mir which had been launched on a Proton carrier rocket at 2129 on February 19.

On March 12, in departure from normal practice, the Soviets announced the impending launch giving names of the crew and the launch time. Soviet TV and radio broadcast the launch live, the first time ever for a domestic Soviet space flight (the launches of Soyuz 19, and Soyuz T-11 were broadcast live but these were part of international flights).

The Soviets were [illegible] at the start about the aims of the flight – [illegible] the most complex of those we intend for the next few years [illegible] Shatalov – and it was announced that the cosmonauts would dock with Mir on March 15 and after a period of time working on the new station would [illegible] to the older Salyut 7 space station on which the two men had spent 237 days in 1984.

The call sign of the spacecraft was "Mayak" ("Beacon") and it was reported [illegible] that the reserve crew consisted of cosmonauts [illegible] and Aleksandrov.

Docking in Orbit

The two-day flight to Mir was one day longer than normal in order to conserve fuel for the flight to Salyut 7. The two stations were in close orbits (*Spaceflight*, May 1986, p.211) and some observers had expected them to dock in early March. Such an event would have been impossible because neither station carries a [illegible] docking unit (both are "drouge" docking units). The large Cosmos 1686 module was still attached to the front of Salyut 7.

Kizim docked Soyuz T-15 with the front docking port at 1338 on March 15. The docking was not televised. It was slightly earlier than planned and the commander had manually approached the station from 200 metres and docked manually.

Opening of the internal hatches between Soyuz and Mir was broadcast live on radio. [illegible] Solovyov – the first to enter – was to [illegible]. Later the two men sent a four minute TV broadcast [illegible] the interior of the Salyut-sized station. [illegible] the main job of the flight was to make [illegible] longer periods by subsequent crews. The Soviets [illegible] at the time of launching the station that it was intended to be the central part of their permanent [illegible] station.

Description of Mir

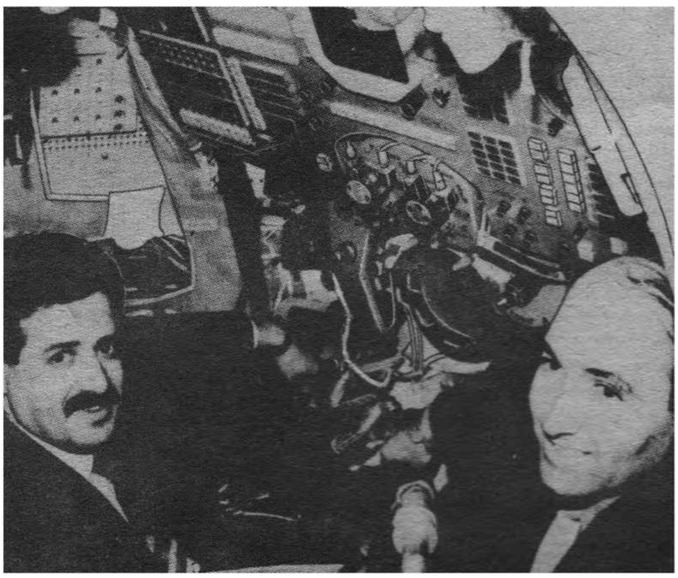
The Mir station is approximately the same size as Salyut 7 but has none of the large scientific equipment aboard it that the earlier station featured. [illegible] that Mir is intended to be the "living quarters" [illegible] complex. Inside the station there are small [illegible] which serve as "dormatories" for the crew. [illegible] provide a degree of privacy not possible [illegible]. There is also a small dining area which [illegible] to warm the foods.

Mir has more onboard computers than Salyut – seven computers against [illegible] – and is said to be more easily controlled both [illegible] the automatic mode. The Soviets say that [illegible] part of the operations on the Mir station [illegible] care of by the onboard computers, which [illegible] select the optimum operating regime.

Exercise equipment is [illegible] compactly, the stationary bike is kept under [illegible] assembled for use and the running track [illegible] located to allow cosmonauts to look along the [illegible] the station rather than at the walls, as on Salyut.

The toilet is a small cubicle [illegible] can also wash

Syrian cosmonauts, Mohammed Faris (left) and Munir Habib, in the simulator room of the Yuri Gagarin Cosmonauts' Training Centre. They are training for a joint Soviet-Syrian space mission. *Novosti*



SOVIET SCENE

their hands and faces in a fountain of water from a valve which is restricted by a transparent "hood" with three openings. Seats are provided which the cosmonauts straddle, grasping the lower sections with their feet and using the upper surface as an extra table.

The interior of the station is divided into two sections – living and working areas. In the work area, where the control post is located, the ceiling is painted white and the walls dark green to give a sense of orientation.

Mir's exterior retains the shape of Salyut but has two highly-efficient wings of solar panels. At the front of Mir is the docking unit which sits atop the small diameter cylinder. A spherical attachment has five docking units set into it – one at the front and one each at 90 degrees around the diameter. The rear of the station is the same as Salyut with the sixth docking unit surrounded by the ODU engine.

The Soviets say that the front and rear docking units will be used for all dockings and the other four units will be used by the unmanned Cosmos modules, similar to Cosmos 1686. After docking with either the front or rear units a special "manipulator" will be used to manoeuvre the heavy Cosmos module to one of the side units. The Soviets have not indicated where the manipulator is located but one report suggests that the modules will carry their own manipulators for the transfer. The Soviets also said that a module could be added behind the station which would have a second docking unit for cargo craft to use. This additional unit has been seen by journalists at Zvyodznyy Gorodok and is featured in a painting published in "Ogonyok".

The Soviets say that several modules will be associated with Mir in the future and will have specialised tasks including astrophysics, Earth observations, materials processing or other processing. The modules will dock periodically with Mir to have their "produce" removed and undergo maintenance. At other periods they will fly free from the complex. The cosmonauts may also visit the modules.

Mir also features a dramatic improvement in communications facilities over Salyut. Whereas on Salyut the station was only visible to radio communications facilities for 15 to 20 minutes per orbit, Mir has a special directional antenna located at the rear of the station which is used to transmit and receive radio and TV via the Soviet SDRN system using three geostationary satellites, at the orbital locations of 95°E, 200°E and 344°E for the relay of signals to FCC. The system is "completely analagous" to the USA's TDRSS system. It operates in the 11-15 GHz band and testing was high on the list of work priorities for Kizim and Solovyov as they settled into Mir.

Working on Mir

The first tasks for the two cosmonauts on Mir involved checking out the station's systems for manned operations, including reactivation of the life-support and temperature control systems. On March 16 the internal temperature was 24 degrees C. Pressure was 860 mm of mercury. The complex was in a 354 x 332 km orbit with a period of 91.2 minutes. Inclination was 51.6 degrees. By March 18 the system for atmospheric water regeneration was in working order.

On March 19, at 1008, Progress 25 was launched from Baikonur to dock with Mir's rear docking unit which it did at 1116 on March 21. The unmanned cargo spacecraft brought about two tonnes of various cargo to the complex including fuel, food, 200 litres of drinking water, tools, film and equipment to be installed on the Mir station. Mail and souvenirs from the cosmonauts' families and friends were also in the cargo.

The next few days were spent unloading the cargo and refuelling Mir's fuel tanks. Orbital altitude was increased 10 km by a manoeuvre performed with the Progress 25 engine.

By March 28 the men had completed unloading the cargo ship. They had also begun their programme of medical checks and physical exercises.

On March 29 the cosmonauts tested out the communications system which uses the relay satellite in geostationary orbit. The first of the "Luch" ("Beam") satellites is stationed at 95°E and was launched on October 25 1985. The satellite was called, on launch, Cosmos 1700. During the test, the cosmonauts sent live TV and FCC. The satellite makes it possible for the control centre to communicate with the complex for some 40 minutes per orbit. Future launches of relay satellites to another two locations will make communication continuous.

To Be Continued

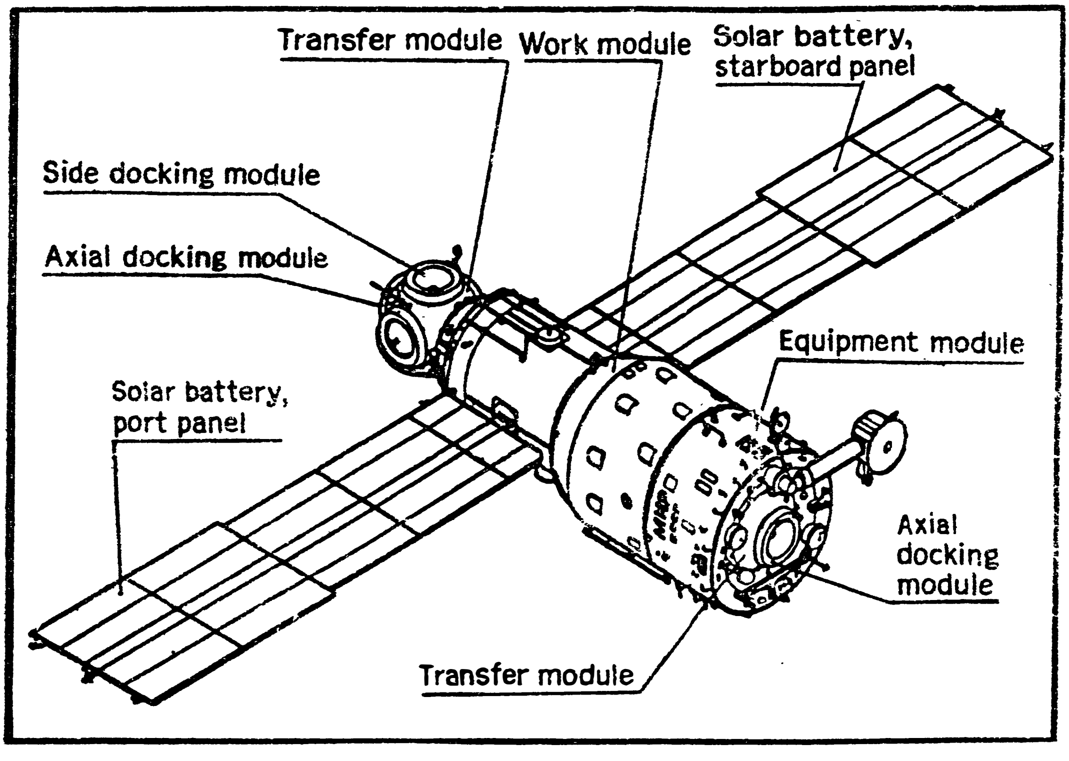


Diagram showing the base unit of the Mirorbital research station. The main docking unit (five ports) is at the front end and sits atop a small diameter cylinder. The rear of the station is similar to Salyut with the sixth docking port surrounded by the ODU engine.

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

SPACE TELESCOPE TEST

The Hubble Space Telescope is now undergoing its most gruelling test at Lockheed Missiles & Space Company, as preparations continue for its launch and projected 15-year mission.

The satellite has been positioned in a thermal-vacuum chamber, simulating, to the extent possible on Earth, conditions it will face when it operates in its 320-nautical mile orbit.

"The thermal-vacuum test is the most demanding workout the vehicle faces," explained Lockheed programme manager Bert Bulkin. "And it is also the most important. We need to confirm our thermal predictions, ensure all systems operate with each other, and go through sample mission timelines as realistically as we can."

While it is impossible to duplicate the exact space environment, especially the absence of gravity, technicians can create enough of a vacuum so that those components of the telescope that can only operate in an air-less environment can be switched on and tested.

At the same time, the vehicle is being heated and cooled to simulate the orbital sunrises and sunsets it will experience during a typical day in space.

To verify that the complex system operates smoothly, engineers will also put the Hubble Telescope through a complete simulated observing sequence. When the pointing control system sends a command to point the telescope toward a star, for example, ground computers will simulate the manoeuvre and provide confirmation, even though the spacecraft will not actually move in the chamber.

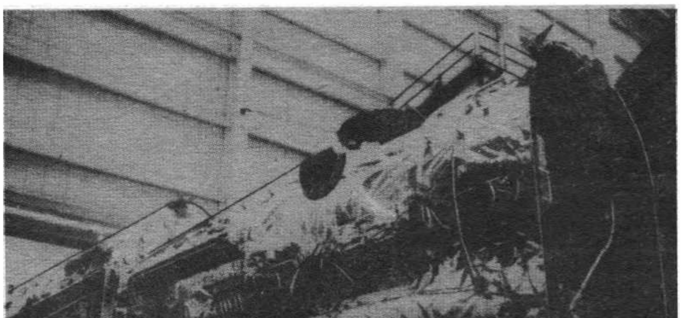
The Hubble Space Telescope will be one of the most thoroughly tested spacecraft ever launched. From a computerised control room, technicians can test the entire vehicle, the subsystems such as data handling hardware, or individual black boxes.

Earlier this year the telescope underwent acoustic tests to simulate launch conditions. Checkout of the vehicle before and after these tests provided valuable data on system performance.

Similar checkout tests will be run after the telescope's 40-day stay in the vacuum chamber and again after the instrument is shipped to the Kennedy Space Center. Even though the vehicle will be in Florida the tests will be run from the same control room in Sunnyvale via satellite.

Prior to the Challenger disaster in January launch of the Space Telescope by the Shuttle was scheduled for this autumn but it is now likely to be at least another 12 months before even a new launch date is allocated.

The Hubble Space Telescope prior to being placed in a thermal vacuum chamber for an extensive series of tests.



SPACE STATION DESIGN DETAILS

NASA has selected a baseline configuration for the permanently manned Space Station. The configuration will be used to guide preliminary design activities for the remaining months of the Phase B studies.

The new model for the [illegible] Space Station is smaller than originally envisaged and is now to be designed so that a crew does not have to be onboard from the beginning.

This is in response to a desire expressed by the US Congress to have the option of tending the station through periodic crew visits during its early stages.

NASA administrator James Fletcher has stated that the permanently manned aspects of the programme would be phased in over three to five years.

The changes have been dictated by US budget constraints and the Space Station, consisting of an array of giant metal trusses about [illegible] metres long and 50 metres wide, will include [illegible] pressurised modules instead of seven as originally planned, with additional modules to be added later.

The United States will provide a habitation module that will hold eight crew members and laboratory modules for logistics and microgravity research. Japan plans to provide an advanced technology module and an attached work deck for mounting experiments requiring direct exposure to space and ESA has proposed a pressurised module for conducting life science and materials processing experiments.

Canada will develop a mobile servicing centre that will be used to help assemble the Space Station in orbit. The service centre will include a remote manipulator arm, similar to the one built by Canada for the Space Shuttle, servicing tools and [illegible].

The Space Station will also include large solar arrays, power stations, and attached experiment and equipment bays. There are also plans for four free-flying unmanned platforms to be provided by the United States and two by the European Space Agency.

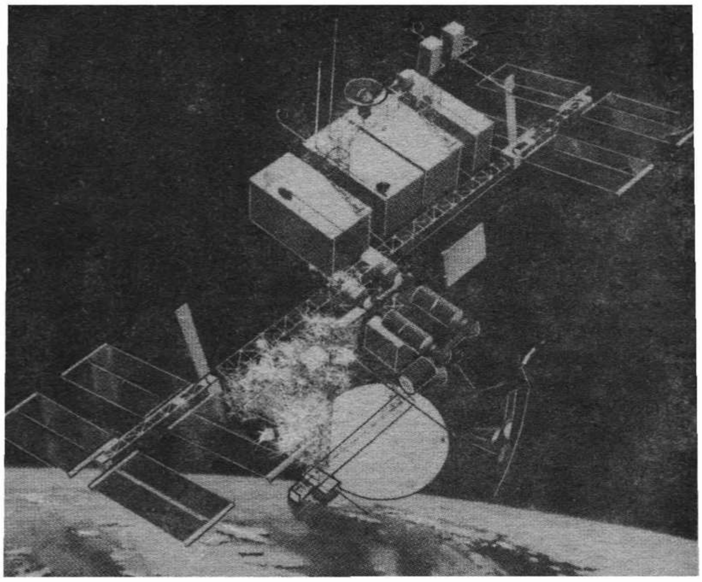
INTERNATIONAL SPACE REPORT

The current schedule calls for work to begin in late 1986 with the first contracts for actual hardware development awarded by May 1987.

First element launch would occur in 1993, with a useful, permanently habitable station in place in 1994. The remaining elements required to complete assembly of the Space Station would be launched over the next two years.

Major features of the baseline configuration are:

- Dual keel configuration consisting of two vertical keels 361 feet long, connected by upper and lower horizontal booms 146 feet long. The former reference configuration consisted of a single keel 400 feet long. The Space Station now measures 503 feet at its widest point from tip to tip of the transverse boom on which the power modules are mounted.
- Two 44.5 feet long, 13.8 feet interior diameter US supplied modules with external interconnects. The reference configuration was four 35 feet long modules with internal interconnects. Useable volume provided by two baseline-size modules is approximately the same as the four originally proposed. One will be a laboratory and the other will be used for crew quarters. Baseline configuration also includes two smaller logistics modules 24.1 feet long. One will be attached to the station for on-orbit use while the other is being replenished on the ground.
- Internal module pressure of 14.7 per square inch and 80/20 nitrogen/oxygen mixture ratio to approximate sea level Earth atmospheric conditions. This atmosphere is compatible with the existing data base for life sciences experiments and due to its normal oxygen content will minimise flammability problems and ease constraints on materials that can be used inside the modules.
- Closed-loop environmental control and life support system. Oxygen and water (including wash water and urine, but excluding fecal water) will be recycled. Portable water will be distilled and nitrogen and food will be resupplied.
- Hybrid solar power system with 75 kilowatts of power at completion of station assembly period. The system will be designed so that 25 kilowatts are provided by the photovoltaic system and 50 kilowatts by the solar dynamics system. Nickel-hydrogen batteries will provide storage for the photovoltaic system to handle eclipse periods.
- Five locations on the structure for placing attached payloads and a facility for servicing free flying spacecraft and platforms.
- Telerobotic servicer as a part of the baseline configuration.
- Polar platform with useful payload on single Shuttle launch. Platform will have maximum equipment commonality with the Space Station such as solar arrays and nickel-hydrogen batteries.
- Co-orbiting platform with systems common to polar platform and manned base which can be used to support astrophysics and materials processing.
- Gaseous hydrogen/oxygen propulsion system for altitude boost with four modules located on the four quadrants of the Space Station.
- Assembly altitude of 220 nautical miles. Operational altitude will be 250 nautical mi. minimum. Frequency of periodic reboost of station to operational altitude will be determined by solar activity.



The dual-keel design for the international Space Station shown here after construction in Earth orbit being serviced by a Space Shuttle.

- Metric as standard unit of measurement. Deviations permitted only where costs of implementing metric are unreasonable.
- Inclusion of international elements into the overall design, including the Canadian Mobile Servicing Center (MSC) and hardware provided by Japan and the European Space Agency. The MSC will include the Space Station remote manipulator system, end effectors, servicing tools, control stations and special purpose dextrous manipulators. NASA will provide the mobile capability for the MSC's base structure. Japan is conducting preliminary design on a pressurised laboratory module with a local manipulator arm, attached work deck for mounting payloads requiring direct exposure to space, and an experiment logistics module. Discussions with ESA will continue to focus on a permanently attached pressurised laboratory for life sciences and materials experiments, a po'ar platform and a co-orbiting platform.

SOLAR TELESCOPE CANCELLED

The Solar Optical Telescope (SOT), a major Shuttle-borne payload originally scheduled to first study the Sun in 1991, has been cancelled, ***writes Joel Powell.***

NASA cited delays and cost escalations in the Spacelab programme as reasons for the deletion of SOT from the Fiscal 1987 budget. Project planners expressed hope that the programme could be scaled down and re-emerge under a new name.

SOT was designed to incorporate a 1.3m telescope with solar resolution of 0 1 seconds on which was to be mounted an ultraviolet-visible light spectrograph with camera and a separate filter-wheel camera. Solar magnetic fields and the interaction of the fields with the convective motion of the Sun's outer layers were to have been a primary research objective. The SOT replacement may involve a one metre telescope using the HRTS or SOUP instruments flown on Sapcelab 2 in July 1985. A German white light spectrograph is also a candidate replacement instrument.

INTERNATIONAL SPACE REPORT

SATELLITE DIGEST – 194

Robert D. Christy

Continued from the June 1986 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

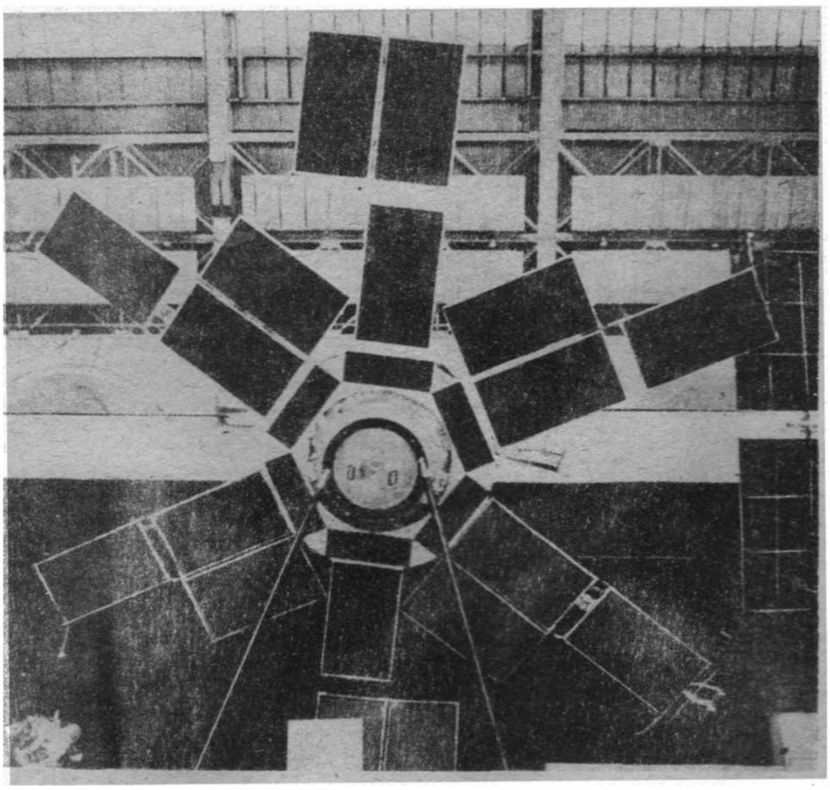
The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1738, 1986-27A, 16667.
Launched: 0345, 4 April 1986 from Tyruatam by D-1-e.
Spacecraft data: Probably similar to the Gorizont satellites, being a stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Possibly Luch Communications satellite providing continuous telephone, telegraphic and television links within the USSR, and extending communications support to the MIR space laboratory.
Orbit: Geosynchronous above 14 degrees west longitude.

COSMOS 1739, 1986-28A, 16677
Launched: 0800, 9 April 1986 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and mass around 6000 kg.
Mission: Military photo-reconnaissance, long duration mission.
Orbit: 173 x 328 km, 89.53 min, 64.89 deg, manoeuvrable.

COSMOS 1740, 1986-29A, 16679
Launched: 1140, 15 April 1986 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and mass around 6000 kg.
Mission: Military photo-reconnaissance, recovered after 13 days.
Orbit: 355 x 416 km, 91.31 min, 72.88 degrees.

The Molniya-3 communications satellite which was put into orbit on April 18.

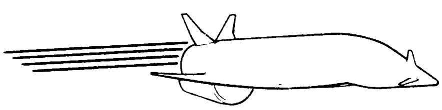


COSMOS 1741, 1986-30A, 16681
Launched: [illegible], 17 April 1986 from Plesetsk by C-1
Spacecraft data: Possibly similar to the Cosmos navigation satellites in having a cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is provided by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Communications satellite using store dump technique.
Orbit: 782 x [illegible] km, [illegible] min, 74.03 degrees

MOLNIYA-3 [illegible], 1986-31A, 16683
Launched: [illegible], 18 April 1986 from Plesetsk by A-2-e
Spacecraft data: Cylindrical body with a conical orbit adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around [illegible] kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially [illegible] km, 736.49 min, 62.82 deg, then lowered to 617 x 39713 kmg, 717.27 min to ensure daily repeats of the ground track.

PROGRESS 26, 1986-32A, 16687
Launched: [illegible]*, 23 April 1986 from Tyuratam by A-2
Spacecraft data: Near-spherical supplies compartment carrying a rendezvous radar tower, covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Unmanned cargo ferry carrying consumables and equipment for the crew of the Mir space laboratory. Some of the cargo may have consisted of spare parts for installation aboard Salyut 7 after the Soyuz 25 crew transferred across on 5/6 May.
Orbit: Initially 184 x 256 km, 88.90 min, 51.63 deg, then manoeuvred to 335 x 344 km, 91.31 min, 51.62 deg for docking with Mir on 26 April

CORRESPONDENCE



Hotol Recommended

Sir, The Delta mishap, the Titan 34D explosions and the Ariane V-18 mishap all illustrate a singular shortcoming with con-ventional launch vehicles: not only are they one-shot devices, but if they malfunction you lose the spacecraft as well. The cost may be affordable if the spacecraft is one of the more or less series-built Hughes Galaxies, but if it is one of the unique, multi-million dollar space probes or great instrument-carriers, like the Hubble Space Telescope, the situation is grave. The potential loss of such a spacecraft is the potential demise of the programme as well.

James A. van Allen, one of the greats in space science, has gone on record promoting exclusively unmanned space flight techniques for space science payloads. With all due respect I find his thinking flawed. Maybe the launches should be unmanned to save a lot of not needed life support, for instance. But the technologies should be "man-rated" in that at least the spacecraft, and preferably the launch vehicle too, should be abortable and recoverable.

There are various ways of accomplishing this. The near-term solution – a sort of recoverable upper stage/protection shroud/return capsule – would be rather easy to implement but would, of course, tax the launch capacity rather severely. The long-term solution is already in the books – a single-stage-to-orbit reusable vehicle, like Hotol.

Along with other excellent reasons for going ahead with Hotol – the first and foremost being the little matter of economy – I think the "man-rating" philosophy of the vehicle and its survivability in the event of a malfunction is a compelling reason to proceed. Hotol may thus suffer a malfunction and still abort to fly another day. A new expendable launch vehicle, as now called for in the US, would just be a matter of "more of the same" – it would not alleviate the basic problem, that of survivability of the payload, vehicle and crew. Unfortunately the Shuttle embodies the worst of both worlds.

In the long run the costs of developing a totally re-flyable, and thus totally abortable launch vehicle, will be more than offset by lower running costs, lower payload costs – as you do not have to build spare spacecraft and test them – and lower insurance as "total failure" rates drop.

Thus, the answer to today's space transportation dilemma lies in a total change of scene. Space flight was born as a side-shot of the military one-flight-mission missile. Space transportation is multi-mission by nature, be it science or commercial exploitation. Spacecraft are multi-mission already, it is high time to make launch vehicles truly multi-mission and multi-flight as well, and remake space transportation into a real transportation venture up to orbit – and down again. As of today, only Hotol is the viable European alternative.

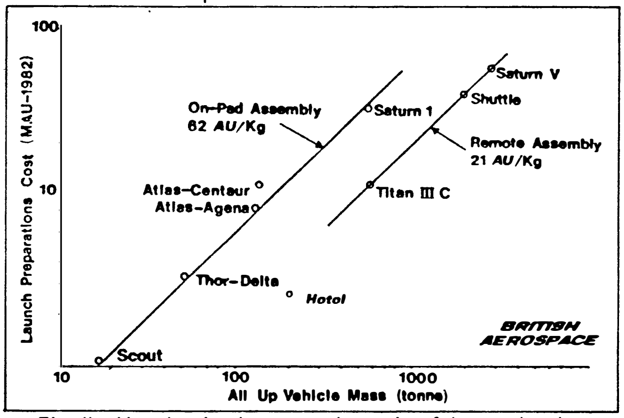
J. WESTMAN
Helsinki, Finland

Hotol Economics

Sir, I reply to Harry Ruppe's letter in the June issue of ***Spaceflight***, where he claims that the Hotol cost savings claims cannot be substantiated. In fact we did a survey of 35 different types of launch vehicle design to establish that the Hotol cost savings were real, and economics continues to be a key part of our studies. Historically launch vehicle design groups and operators have seemed reluctant to give deep insight into the basis for their price, and that makes our task somewhat more difficult, but we believe we now have a good understanding.

The first major gain is to have a recoverable vehicle. Hardware which is only used once, as with Ariane or the Shuttle, is expensive no matter how simply it is made. The Shuttle External Tanks cost $17m a launch.

With a recoverable vehicle, launch operations costs become important. The illustration shows that historically launch operations costs have been a function of lift-off mass, not inert mass, with a factor for the way the vehicle is handled. The Shuttle has an improved launch processing system, but has not yet achieved a gain over the specific operations costs of Saturn V because handling a recoverable vehicle is inherently more complex. In the case of Hotol, our studies indicate we can achieve 10 AU/kg, and the principal reason is that we do not have to integrate a multi-component vehicle. The same might be true of a rocket-powered single-stage-to-orbit vehicle, but it would be considerably bigger, and so would the operational costs.



Finally, Hotol gains because the ratio of the payload mass to the mass of expensive machinery is about twice that for a single-stage-to-orbit rocket. That is important not only for recurring costs but for development costs. Our studies continue to show a cost-per-kilogramme gain over Shuttle prices of five to seven times at the sort of utilisation Europe can expect to require from its launcher. Some of the larger gains quoted by NASA studies would demand greater utilisation and larger launch vehicles, but in all things we have attempted to be realistic. Hotol remains a good option for Europe.

R.C. PARKINSON
British Aerospace

Uranometria

Sir, I was interested in the fascinating story of the Society's copy of the *Uranometria* – an 18th century "who-dunnit" and agree that the observer is unlikely to have been Bradley! He would have been unlikely to have given up once he had started, nor would he have thought in terms of producing something for ornament. Also, Bevis had written to him in December 1748 mentioning his atlas in a way that implied that Bradley already knew about it (Bradley's Miscellaneous Works, p.456). If Bradley had been the observer, he would surely have given up before 1749.

The only serious alternative candidate I am able to suggest is Stephen Bolton, Rector of Stalbridge, Dorset. He might well have had the leisure and the interest, but was a Cambridge man; and I have no evidence that he was in contact with Bliss. I have been able to find out very little about Bliss, and cannot really suggest who he was in correspondence with.

I believe that the "Royal" watermark GIR does not signify that the paper originated from government or Royal sources and could be misleading.

RUTH WALLIS
Newcastle upon Tyne

CORRESPONDENCE

International Cooperation

Sir, The US National Commission on Space has recently produced a report detailing an ambitious expansion of Solar System exploration and exploitation (see Nature, vol. 200, p.563 for a summary of the report's proposals and ***Spaceflight,*** May 1986, p.194). There is much that we should welcome in this report, advocating as it does manned exploration of both the Moon and Mars, complete with permanent bases, and the exploitation of lunar resources, although this latter point presumably depends upon such resources being found in an economically viable concentration. There is, however, a major cause for disappointment in its recommendations, namely its argument against ratification of the UN Moon Treaty.

The Moon Treaty, known officially as the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, and opened for signature in December 1979, was an attempt to internationalise the economic exploitation of the Solar System. It has been attacked on the grounds that international regulations would inhibit US enterprise in Space. This is the same argument, incidently, that led to the failure of the United States to ratify the International Law of the Sea, or perhaps Willy Brandt[1] was nearer the truth when he said: "The fact was that certain large companies did not want to subscribe to a system of international law." In any case a great opportunity for international cooperation in the exploitation of globally common raw materials was missed, just as it looks like being missed in the exploration and exploitation of outer space. To what extent is the Moon Treaty really a threat to the development of the Solar System?

The underlying philosophy of the Treaty is set out in Article 4, paragraph 1: "The exploration and use of the Moon shall be the province of all mankind and shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development..." In support of this the Treaty aims to set up an international regime for the organisation and distribution of lunar resources (and extra-terrestrial resources in general) for the economic benefit of all nations, just as the Law of the Sea had intended to do for the resources of the sea bed. Clearly, like all large international bureaucracies, such an organisation could very well introduce inefficiencies in the economic exploitation of the Solar System, although many would argue that this would be a relatively small price to pay for keeping the Solar System free from national competition and at the same time aiding the development of the poorer parts of Earth. This view was stressed in the 1982 Unispace Report [2], in particular in paragraph [illegible]

However, the large scale economic exploitation of the Solar System is [illegible] in the future. The Moon Treaty advocates nothing that need slow down the exploration of the Solar System by the United States or by anybody else. Article [illegible] paragraph [illegible] permits States to use whatever [illegible] their explorations. [illegible] their own activities including manned bases on the Moon without interference from other States [illegible] necessary to ensure [illegible] provisions of the Treaty. Article [illegible] paragraph [illegible] ensures that individual nations retain the ownership of [illegible] equipment placed by them on the Moon or [illegible]. Moreover, there is plenty of scope [illegible] for revising the Treaty once exploration [illegible]

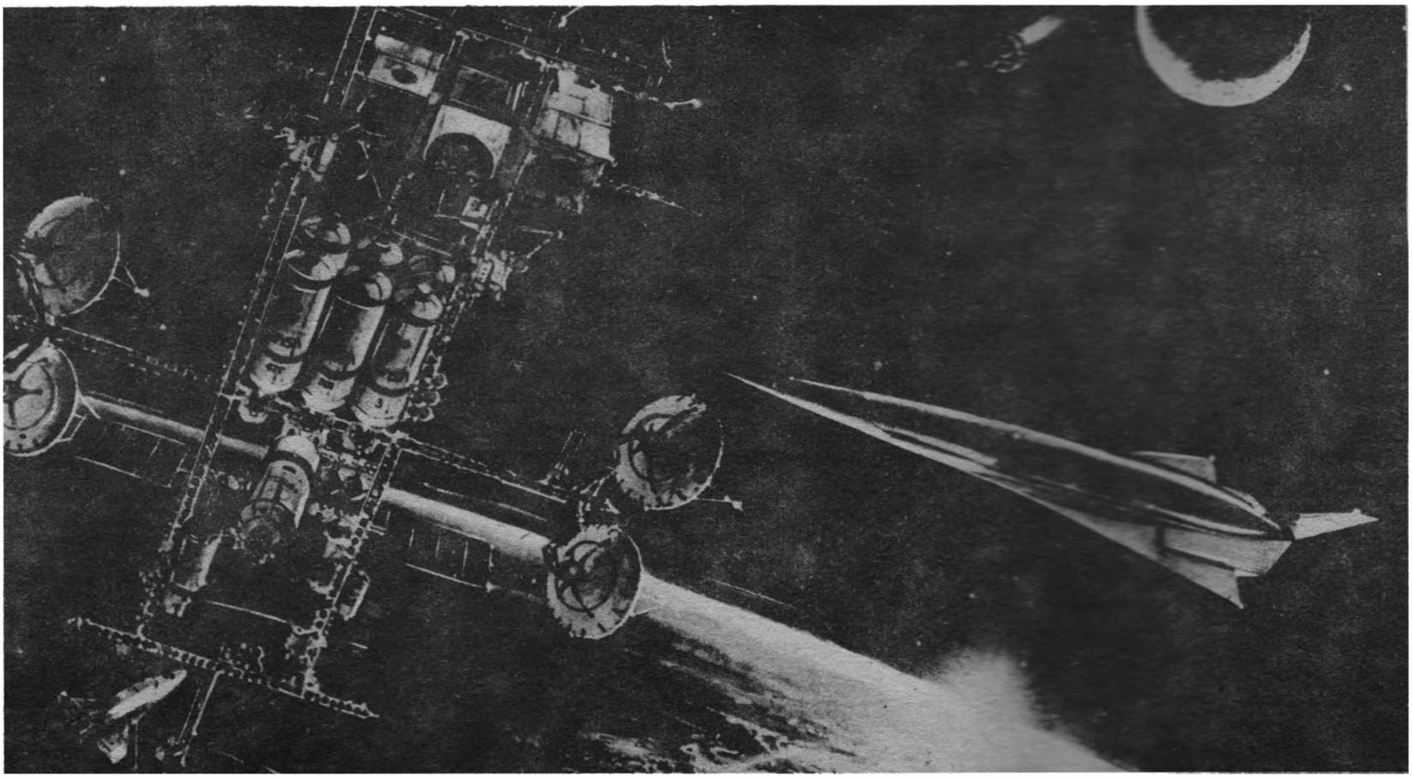
Thus, we see that the Moon Treaty need not in anyway inhibit the exploration of Space [illegible] to further place such exploration [illegible] international law, and in the long term [illegible] the benefits from Space available to all [illegible] might not be popular with large companies [illegible] interests (as with the Law of the Sea) [illegible] companies will get plenty of business [illegible] supplying the hardware, there is no just reason for not ensuring that the material benefits of the Solar System reach the whole of humanity.

[illegible] CRAWFORD
[illegible] London

REFERENCES

1. Willy Brandt, "World [illegible]" English edition, Victor Gollancz Ltd, London [illegible]
2. Report of the Second UN Conference on [illegible] Peaceful Uses of Outer Space. UN document [illegible]

The US National Commission on Space suggests a series of Spaceports to act as bridging points for missions between [illegible] Spaceport in Earth orbit receives supplies from a cargo transport vehicle (lower left). In the distance a two stage transfer vehicle [illegible] by ***Robert McCall***, Bantam Books.



Lunar Bases and Space Activities of the 21st Century

Ed. W. W. Mendell, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, Texas 77058-4399, USA. 1986, 865 pp, S20.00.

This is a collection of short papers dealing with various aspects of a manned lunar base and with manned exploration of near-Earth space, most of which were delivered at a symposium sponsored by NASA in 1984.

To some extent the papers presented draw on the texts of earlier meetings and the Report of the Lunar Base Working Group, though this was not a formal part of any NASA advanced planning activity, for official NASA studies of Lunar Bases ceased in 1972.

The motivation for the present collection of papers is based, largely, on the concept that Space Transportation Systems by the year 2000 should be capable of delivering payloads to the Moon – hence, the fabrication of a lunar base becomes of prime significance. Such a development would enhance the scale of space exploration by an order of magnitude over current programmes so it is imperative to identify, at the earliest possible stages, all avenues of industrial and scientific exploitation opened up to civilian use.

There is no doubt that the development of colonies on the Moon and elsewhere will represent a major coming-of-age both of the space community and mankind: all else are preliminaries. The establishment of a lunar base has always been to the fore in BIS thinking and promoted by it from its earliest days. Even the early concept that "the Moon is a good place to get away from" is as valid now as it was five decades ago. The question is, will we live to see it?

This book not only attempts to bring that day forward but to pose many of the exciting new possibilities thereby opened up. The ambition of the book is at best set out by its choice of the final contributor, no less than the late Krafft Enricke, a visionary of no mean order and whose loss is sadly missed.

Jane's Aerospace Dictionary

B. Gunston, Jane's Publishing Company Ltd., 238 City Road, London, EC1V 2PU, 565 pp, 1986, £20.00.

In attempting to keep pace with developments in the international world of aerospace, this second edition of a comprehensive directory, now running to some 20,000 entries, has been completely revised, including the addition of a further 6,000 new forms.

The dictionary draws entries from terms in the many disciplines that contribute to aerospace, including data processing, materials science, electronics, meteorology and medicine. Also included are: Acronyms, voice communications codes (military and civil); the basic equations of aerodynamics, electronics, rocketry and many other aerospace-related fields; materials and fuels and their specifications; military terminology relating to conventional and nuclear weapons delivered by aircraft and missiles; Soviet reporting names and US electronic equipment designations.

Entries are presented in strict alphabetical order. Where more than one meaning for a word exists, these have been numbered and listed. Besides that, the dictionary is extensively cross-referenced, with sources indicated where necessary.

The result is a major work of reference to anyone who seeks to understand many of the key technologies of the 20th Century related to aerospace.

Dictionary of Space

M. Plant, Longman Group Ltd., Longmand House, Burnt Mill, Harlow, Essex, CM20 2JE. 270 pp, 1986, £10.95.

It is always interesting to see a new space dictionary, if only to appreciate the enormous developments which take place over a relatively short period of time and which quickly out-date earlier references.

This handy dictionary, with over 2,500 definitions, explains the concepts, language and broader implications of space exploration in a way that will interest everyone. It is a most interesting compilation covering a wide range of discoveries about planets, comets and other astronomical objects, as well as spacecraft and manned space activities.

The only error noted related to Black Knight, also referred to under Black Arrow. In both cases it appears Black Night.

We are most appreciative of the fact that the author, a Fellow of the Society, has included a number of references to our work.

Sun and Earth

H. Friedman, W. H. Freeman & Co. Ltd. 20 Beaumont Street, Oxford, OX1 2NQ. 1985, £15.95, 251pp.

Generations of men have been enthralled by the subtle beauties of colour and light in the sky, for example in the form of the rainbow or even the blue of the sky itself, and intrigued by the light and warmth of the Sun which sustains all forms of life on Earth.

It was not until late in the 19th century that scientists began to appreciate the prodigious outpourings of energy from the Sun and became aware of the intricacies of Sun-Earth interactions.

By the mid-20th century the true complexity of this interaction was being appreciated, thus disposing of the then prevailing views that the Earth and Sun faced each other across a near-perfect vacuum, transversed only by a calm and invariable flow of light and heat.

We realise now that the Earth is really afloat in a sea of particle radiation and meteoric debris, is constantly buffeted by a wind of gas streaming from the Sun and frequently bombarded by storms of energetic protons, ultra-violet light and x-rays.

This book combines historical narrative of scientific thought on such matters from Galileo to the Space Shuttle. It provides an updated picture of how the Sun shapes our environment and of the impact of solar variability on such problems as radio communiction, the survival of astronauts and spacecraft and the continuing existence of life on Earth.

Remote Sounding of Atmospheres

J. T. Houghton, F. W. Taylor and C. D. Rodgers, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU. 1986, 343 pp. £12.95 ($24.95).

Remote sensing has grown so rapidly in recent years that it is now one of the most important experimental techniques applied in the Earth and planetary sciences. This is due to the wider availability of space platforms from which to make such observations plus the tremendous growth in the computer power to manipulate and anlayse the enormous data involved. This rapid progress, in both areas, shows no sign of abating in the foreseeable future.

The text in this work presents the basic principles of remote sounding and describes applications already made to the study of the atmospheres of the Earth and planets. It includes descriptions of the scientific principles, technical data and an explanation of the mathematical methods adopted for analysing measurements.

Three final chapters look beyond the Earth and consider remote sounding of the atmospheres of other planets in our Solar System.

First Steps Toward Space

Eds: F. C. Durant III and G. [illegible] Inc., PO Box 28130, San Diego, Cal. 92[illegible] 1985, $45.00.

This is the first in a series of [illegible] will reprint papers presented at [illegible] of the International Academy of Astronautics from 1967 to the present time. This [illegible] first two such symposia, those [illegible]

It presents a [illegible] on early space pioneers, rocketry [illegible] propulsion and materials, [illegible] histories of astrodynamics [illegible]

Members [illegible] includes an account of [illegible] our own Society [illegible] the late Harry Ross.

Typical [illegible] merits or otherwise [illegible] true, it was [illegible]

Astronomy and Astronautics

[illegible] London, [illegible]

[illegible] the time [illegible] to keep [illegible]

[illegible] books and [illegible] books and [illegible] nearly all [illegible] provide information [illegible]

The items [illegible] level of readership, ranging [illegible] and expanding into [illegible] works of interest to the professional.

A considerable [illegible] into the compilation. Great [illegible] libraries anxious to compare [illegible] check-list of available material.

A Space Policy for Australia

Australian Academy of [illegible] Clunies Ross House, 191 [illegible] Australia 3052. 194 pp, 1985 [illegible]

This report was [illegible] ation from the Australian Minister for Science [illegible] position of Space Science and Technology [illegible] assesses the need for an Australian [illegible] compares it with present Australian [illegible] examining the markets and opportunities [illegible] out as a result of a more [illegible] roles of government and industry [illegible] along with those policy matters [illegible] determined. Finally, the matter of funding [illegible] dealt with, ending with an overview of the space programmes of many other countries.

Viruses from Space

F. Hoyle *et al* University College Cardiff Press. University College, P.O. Box 78, Cardiff [illegible] 1986, £5.95.

This book develops further [illegible] its authors that viruses and bacteria [illegible] epidemic diseases of plants and animals [illegible] They argue that diseases such as influenza [illegible] no evidence of person-to-person transmission [illegible] arise in this manner.

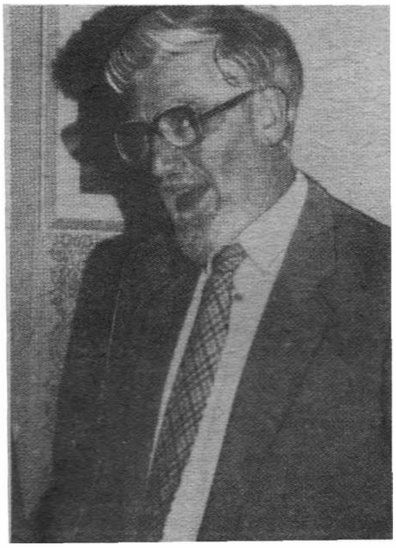
Even for infectious diseases [illegible] the virus, according to this theory [illegible] instance from space and then proceeds [illegible] for person-to-person infection.

News . . . Society News . . . Society News . . . Society News . . . Society

STEPPING STONE TO SPACE EXPLORATION

Roy Gibson (left), Director-General of the British National Space Centre, chats to Society President Mr Rex Turner during a break in the meeting.

S.R. Dauncey who spoke on the International Use of Space Station Facilities.



Dr. J.F Padday who presented a paper on The Realities of Processing in Space.

The Society's meeting on Space Station Exploitation, held in its Conference Room on May 21/22, 1986 was outstanding both for the high standard of papers presented and for the informed nature of the discussions.

It was third in a series concerned with an in-depth examination of potential British and European involvement in Space Station structure, management and operation.

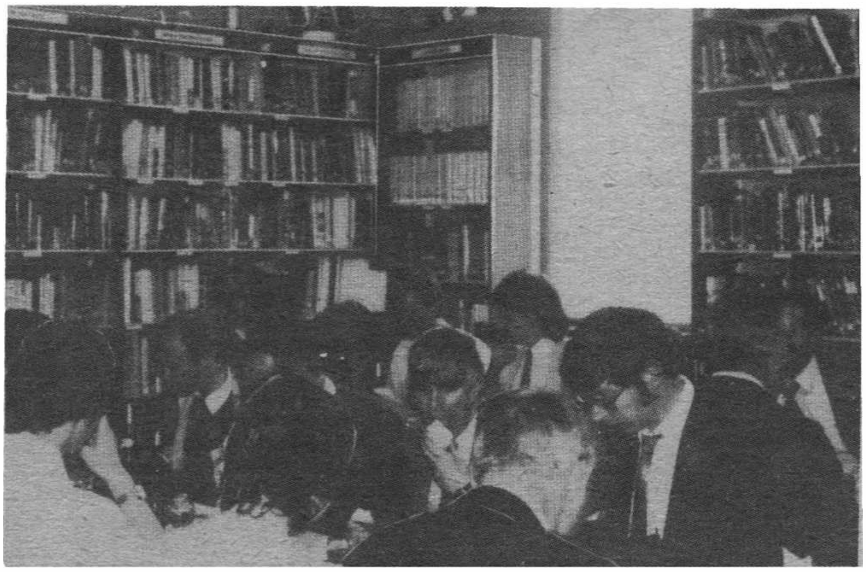
Areas dealt with at earlier meetings urged involvement in the core programme, rather than peripherals, with free-flying platforms as an interesting illustration as to how the technology could be further developed. Subsequent discussions expanded this to include management and operation problems in which stress was placed not only on the need for representation during all phases of construction but also in long-term management operation plans.

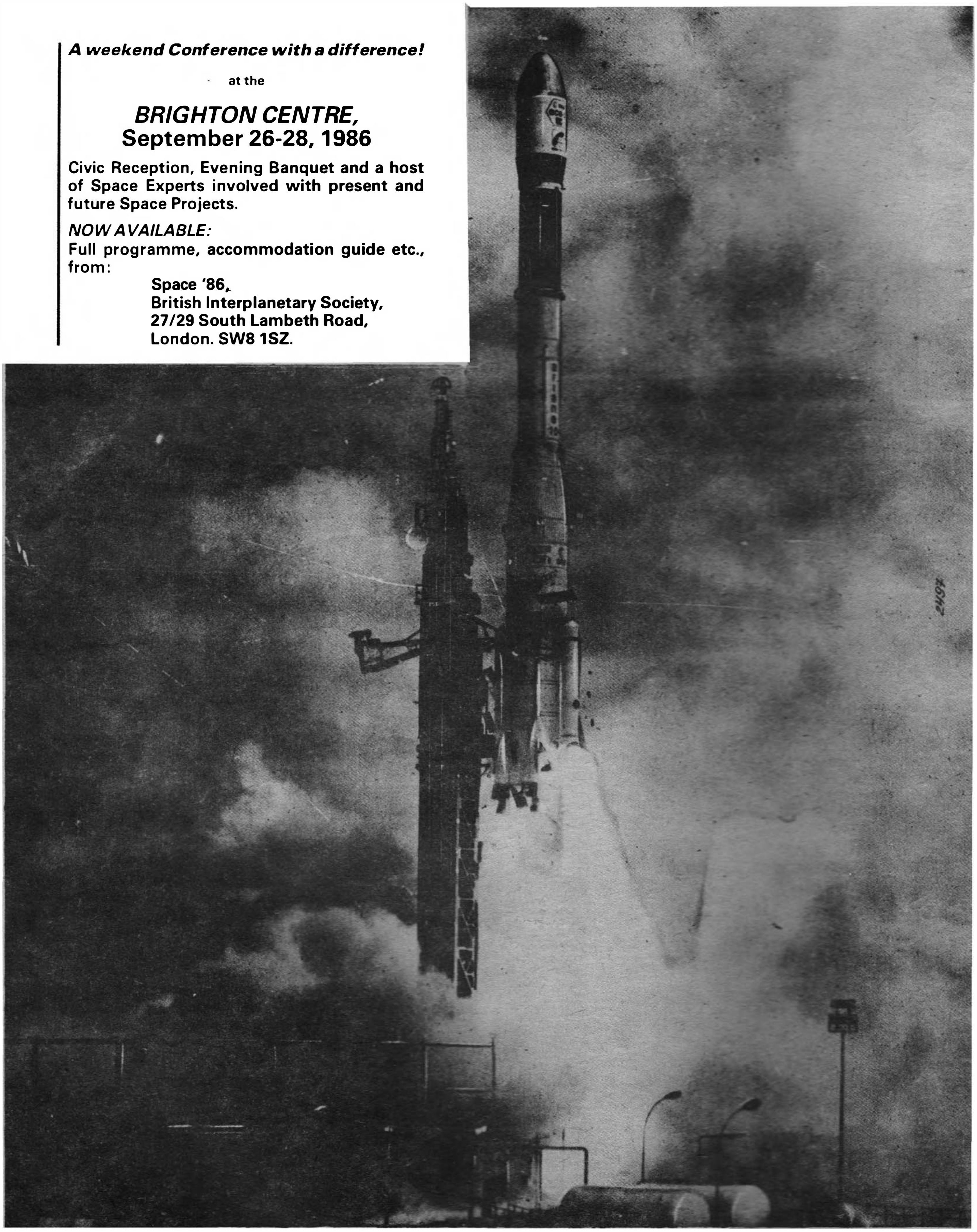
Our third meeting developed further some of the possibilities for practical applications of a Space Station, mainly applied to Earth-orientated and man-related ventures, but breaking new ground with ideas and concepts in areas yet to be exploited.

An announcement will be made about our 4th Symposium in this series in due course. Its theme will be "Beyond the Space Station" and will attempt to evaluate the use of the Space Station as a stepping stone to the Moon and planets and to the exploration of outer space for long-duration missions.

Participants browse through Society publications

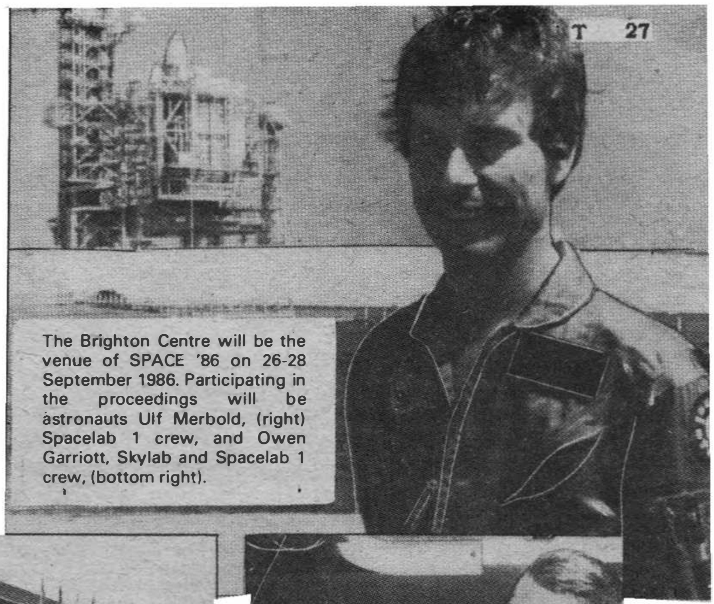
The Society library provides an appropriate setting for lunch.




2497

SPACE: PROFILES OF THE FUTURE

Never before have events in Space commanded so much attention as now and by so many sections of the community. Industry in particular is increasingly recognising the commercial opportunities offered by Space. For the first time the UK is developing a coordinated national space plan managed by the newly-created British National Space Centre and hopes are raised for increased involvement in international space projects. The BIS is pleased to respond to these developments with the holding of SPACE '86, the third in its series of biennial weekend SPACE conferences and a major International Space Event of 1986.



The Brighton Centre will be the venue of SPACE '86 on 26-28 September 1986. Participating in the proceedings will be astronauts Ulf Merbold, (right) Spacelab 1 crew, and Owen Garriott, Skylab and Spacelab 1 crew, (bottom right).

Conference Theme

SPACE '86 has the theme "SPACE: Profiles of the Future" and within this context presents the main directions in which space events are moving and highlights the factors that will be influencing future policy and decision-making. SPACE '86 will take participants 'behind the headlines' to meet and hear first-hand from those who sit in the 'action seats' and are among the leading Space Experts in the UK, Europe and the USA. Speakers include Dr Reimar Lust, Director-General of the European Space Agency; Roy Gibson, Director-General of the British National Space Centre; Jesse Moore, Director of NASA's Johnson Space Center; Prof Graham Smith, Astronomer Royal; Prof J.L. Culhane, Director of the Mullard Space Science Laboratory; Dr Gary Hunt, Director of the Remote Sensing Unit, Imperial College, London; Dr R.C. Parkinson, British Aerospace; Dr D.J. Shapland, of the ESA Astronaut Office and many others representing a galaxy of space expertise.

Overviews on Space

Expanding opportunities offered by Space programmes, new developments in space technology and space applications, and our increased understanding of the Universe are all sub-themes of this Conference to be profiled into the future.

Important factors in these considerations will be Hotol, the Space Station, the Columbus Space Programme, Earth Observation, Microgravity, Robotics, Computing and the role of men in space.

Meet the Astronauts

No better account of the meaning and realities of Space can be given than by those who have trained or worked in space. The Conference will be attended by astronauts Claude Nicollier (ESA scientist-astronaut), Ulf Merbold (Spacelab 1 crew), Owen Garriott (Skylab and Spacelab crew) and the four UK astronauts; the Conference programme will include Astronaut Presentations and a Question-and-Answer session.

Social Events

Participants are invited (together with accompanying spouse or near relative) to attend an Opening Reception given by Brighton Corporation on the Friday evening and a Banquet arranged by the BIS on the Saturday evening. Accompanying persons are at liberty to attend any of the Conference sessions if they so wish and they will also have the opportunity of joining a private one and a half hour tour of the Brighton Pavilion, with coffee provided.

Hotel Accommodation

Ample accommodation is available among Brighton's 160 hotels and guest houses. All major hotels are situated within about three minutes walk of the Brighton Centre. A FREE accommodation-finding and reservation service is provided by Brighton Resort Services Department.

Registration

Early registration is recommended as seating is limited.

Registration Fees	**Full Session**	
Non-Members	£40	($60)
Society Members	£35	($52)
Members under the age of 21	£15	($22]
Accompanying Person	£ 6	($ 9)
4-course Banquet Ticket (including wines)	£20	($30)
Opening Cocktail Reception	Free	
Tour of Royal Pavilion	1.50	($ 3)

REGISTRATION FORM for SPACE '86, September 26-28, 1986

Please send to: Space '86, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, England.

NAME ....

(ACCOMPANIED BY: ....)

ADDRESS: ....

....

AFFILIATION AND POSITION: ....

.... TEL: .... EXTN: ....

Please register me/us for Space '86. I enclose:

REGISTRATION FEE AND OPENING RECEPTION FEE £

BANQUET TICKETS £

TOUR OF ROYAL PAVILION £

The above covers Registration, Opening Reception, mid-morning and mid-afternoon refreshments and complimentary material distributed at the meeting.

SPECIAL NOTES

1 A full programme will be issued to every participant in due course. Although every attempt will be made to adhere to the published programme, the Society cannot be held responsible for changes due to reasons outside its control.

2. The full fee is payable in advance and includes attendance at all sessions during the conference including Opening Cocktail Reception, coffee and tea breaks and complimentary materials. The fee does not include hotel accommodation. Registration Fees are non-refundable.

3. Hotel accommodation can be handled by Brighton Resort Services Department. A wide range of accommodation is available. Those who wish to make use of this service please tick here. ☐

SOCIETY ENJOYS SUCCESSFUL YEAR

Introduction

During 1985 the Society continued to consolidate its position achieved through the continuing efforts of a dedicated staff and officers and the support of its members. Attention was focussed on these efforts being maintained and even increased in the future so that momentum could be sustained.

The high standard of the Society's publications was maintained regarding both quality and publication schedule. Also, an attractive programme of technical symposia, specialised lectures, film shows and special events was successfully planned and executed, whilst the Society was capably represented at major relevant national and international events during the year.

The Society can therefore feel justifiably satisfied with the year's accomplishments which were achieved without any increase in subscription fees from the previous year.

Meetings and Special Events

The programme of meetings now held almost exclusively at the Society's Headquarters provided a topical forum for discussing the major space events and activities of the year. Mention should be made of the one-day symposium in April on 'Space Stations', a particularly relevant subject in view of the envisaged international collaboration on a space station initiated by the USA in 1984/85 and now under intensive study. This symposium attracted a capacity audience and a second part on 'Space Station Applications' was held in September, again attracting a capacity audience. On much the same theme the Society co-sponsored a 2-day symposium organised by the DGLR at Bad Godesburg in October, entitled 'Towards Columbus and the Space Station'. In addition, a further symposium updating the Soviet Space Programme was held in June. Apart from the meetings mentioned above, many lectures were presented demonstrating the Society's scientific role as well as that in space technology and engineering.

In June the Society organised a special dinner at the Headquarters to honour the four potential UK astronauts: Sqn Leader Nigel Wood, his back-up Lt. Col. Richard Farrimond; and Cdr. Peter Longhurst and his back-up Mr. Christopher Holmes. Sqn Leader Wood, on behalf of his fellow astronauts, referred to UK space achievements in the past and the need for manned UK participation in the future. The evening concluded with a question and answer session.

Events at which the Society was represented included the 23rd European Space Symposium, organised by the AAS and co-sponsored by the BIS, which was attended by the Executive Secretary, and the 36th IAF Congress held at Stockholm (Peaceful Space and Global Problems of Mankind), attended by the Executive Secretary, Dr. L. R. Shepherd and many other BIS members.

During 1985 the Society began preparations for 'Space '86', the third meeting of this successful biennial Conference, to be held at Brighton in September, with the topical theme 'Space: Profiles of the Future'. During 1985, the Society's conference staff undertook a detailed review of meetings facilities in the UK suitable for holding the 38th IAF Congress in 1987; and subsequently the International Astronautical Federation accepted our invitation to host that Congress at Brighton during 11-16 October 1987.

Publications

Ten issues of ***Spaceflight*** were published in 1985 providing articles of general and topical interest as well as news of the Society's activities.

Over 60 authored articles were published and we are grateful to our many writers for the material. The on-going coverage of Space news and events which ***Spaceflight*** presents owes much to those who write for us regularly. For multiple contributions during 1985 we thank particularly Dr. W.I. McLaughlin (Space at JPL), Robert D. Christy (Satellite Digest), Prof John Griffith (Astronomical Notebook), Neville Kidger (Salyut Mission Report) and Gordon L. Harris (News from the Cape). A topic of recurring mention was Halley's comet and the index of the year's contents provides a useful list of articles on the comet, which perhaps may be useful to the editor of ***Spaceflight*** in the year 2061.

JBIS published 73 specialist papers in 1985 in 12 monthly issues under the editorships of Mitchell R. Sharpe, Dr. A.R. Martin, Dr. W.I. McLaughlin, L.J. Carter and A. Wilson. As in previous years, each issue of ***JBIS*** has been devoted to a particular subject area; and, in 1985 the following titles appeared: Space Technology, Space Stations, Solar System Exploration, Mission Systems, Astronautics History, Soviet Astronautics, Interstellar Studies and Space Chronicle.

Educational aspects of Space have continued to develop in 1985 and the Society's publication ***Space Education*** has filled a useful role with the publication of 17 articles in the two planned issues of the magazine.

A tribute is due to the editors, editing staff and to the Society's staff for the effort put into our publishing activity. A major part of the material which the Society publishes is contributed by members, and members have been requested to submit material that might be of interest to the Society, especially for the specialised issues of the Journal.

Committees

The Programme Committee has monitored and supervised our symposia and meetings at Headquarters as well as the special events that require planning well in advance such as Space 86. Important activities of a continuing nature have been the responsibility of other Committees such as the Library and Facilities Committees, and the History Working Group.

The Council appreciates the work of all Committee members and hopes that the Society will continue to benefit from their support and expertise.

Library

Apart from the natural growth of material through current publications of all kinds the acquisition of historic and rare books and documents has continued

Report of the Council for the year ending December 31, 1985

but is a slow business as the cost of 'Collector's items' is becoming prohibitive. Members have been invited to advise the Executive Secretary if they learn of any possible acquisition.

The Library Committee also recommended to the Council that the Society should embark upon an archive collection which would embrace not only books but space-related artifacts. Naturally this will be a long term project for considerable thought has to be given to storage, layout and preservation, among other things.

Constitution

An Extraordinary General Meeting on the 28th September adopted amendments to the Society's Constitution which have brought us into line with other learned societies. Membership is now available in two grades: Corporate Fellowship and Non-Corporate Membership.

Membership

The membership of the Society at the 31 December 1985 compared with that at the 31 December 1984 is as follows:

	31.12 85	31.12.84
Fellows	1666	1648
Members	1741	1752
	3407	3400

Financial

This has not been one of our better years, with Expenditure and Income coming out roughly in balance. The situation arises partly from our wish to hold fees steady for as long as possible and emphasises our need to secure a considerable expansion in membership.

Development Appeal

Contributions to this Appeal are always most gratefully received and continue to be urgently needed to meet the Society's modernisation and expansion programme. We would like to go ahead, as soon as possible, with building an extension to our premises to provide a more spacious conference room, and thus improve the accommodation for our meetings as well as enlarging our library and other facilities for members.

Those who visit our premises are invariably impressed by the progress achieved since the property was acquired, and will know how effectively funds from the development appeal have already been used.

Staff

No report of the Council can possibly be complete without including a hearty vote of thanks to the Society's staff for its contribution to the year's activity. In addition to our indefatigable Executive Secretary Mr. Len Carter and his equally industrious assistant, Ms Shirley Jones, we should also thank the other full time staff members: Messrs A. Wilson and C. Simpson, Mrs. N. Mandry, Mrs. L. Lawford and Ms E. Buttinger; and Messrs P.R Freshwater, E.M. Waine and M.W. Wholey, who have provided part time assistance.

Conclusion

The Society has enjoyed a successful year. It has maintained its activities regarding meetings, special events, representation at national and international functions, while continuing to provide high standard publications for its members. In 1986 we look forward to Space '86 and to the holding of the International Astronautical Congress in the UK the following year.

The four British astronauts at the special Dinner held in their Honour at the Society's HQ in June 1985. From the left are: Mr Holmes, Lt. Col. Farrimond, Miss Tina Buttinger (BIS staff), Sqn. Ldr. Wood and Cdr. Longhurst.

C.R.Turner
President

1985 ACCOUNTS

Report of the Auditors

We have audited the financial statements set out below in accordance with approved Auditing Standards.

In our opinion the financial statements, which have been prepared under the historical cost convention, give a true and fair view of the state of affairs of the Society at 31st December 1985 and of the result for the year ended on that date and comply with the Companies Act 1985.

The financial statements do not specify the manner in which the operations of the Society have been financed or in which its financial resources have been used during the year as required by Statement of Standard Accounting Practice No. 10.

Frazer Keen
Chartered Accountants
4 London Wall Buildings.
London EC2M 5NT

Income and Expenditure for Year Ended 31st December 1985

	Notes	**1985**	**1984**
	2	£	£
Turnover	2	143,212	141,985
Cost of Sales		(97,902)	(86,490)
Gross Profit		45,310	55,495
Administrative Expenses		(67,817)	(60,413)
Operating Loss	3	(22,507)	(4,918)
Interest Receivable	5	18,734	14,933
(Deficit)/Surplus before taxation		(3,773)	10,015
Taxation	6	–	–
(Defecit)/Surplus for the year		(3,773)	10,015
Balance brought forwarad		175,606	165,591
		171,833	175,606
Appropriation			
Pension Fund Monies Invested		(62,310)	–
Balance Carried Forward		£109,523	£175,606

Balance Sheet as at 31st December 1985

	Notes	1985 £	1985 £	1984 £	1984 £
Fixed Assets					
Tangible Assets	7	53,218		74 380	
Investments	8	37,700		88 225	
			90,918		162,585
Current Assets					
Stock		3,889		642	
Debtors	9	1,892		1,184	
Cash at banks	10	37,173		27,820	
		42,954		29,646	
Liabilities due within one year					
Sundry Creditors		24,349		16,625	
Net Current Assets			18,605		13,021
			£109,523		£175,606
Represented by.					
Accumulated Fund	11		£109,523		£175,606

Notes to and forming part of the Financial Statements for the year ended 31st December 1985 Balance Sheet as at 31st December 1985

NOTES

1. Accounting Policies

(a) Depreciation

Depreciation has been provided at rates which are considered appropriate in reducing the cost of the assets to their residual value over their estimated useful life. The rates used are:

Freehold Buildings – 2% on a straight line basis

Fixture, Fittings and Equipment – 10% on a straight line basis except for certain equipment at 25% on a reducing balance basis

(b) Stocks

Stock consists of books and sundry items valued at the lower of cost or net realisable value by the Executive Secretary.

(c) Income from overseas subscribers

The sterling equivalent of overseas subscriptions levied in foreign currencies is credited to Subscription Income. Any Surplus arising on the conversion of foreign currency receipts to the sterling equivalent are applied to the freehold property fund.

2. Turnover

Turnover represents subscriptions receivable and income from the sale of publications.

3. Operating Loss after charging:

	1985	1984
Auditors Remuneration	545	500
Depreciation	2,856	2,856

4. Staff Costs

Salaries and Wages	35,828	28,569
Social Security Costs	4,374	3,843
	£40,202	£32,412

The average number of employees during the year was made up as follows:

Office and Administration	9	6

5. Interest Receivable

Bank deposit interest	£18,734	£14,933

6. The Society has no liability to Corporation Tax.

7. Fixed Assets

	Freehold Land and Buildings £	Fixtures Equipment and Library £	Total £
Cost			
Balance at 1.1.85	176,768	49 302	226,070
Additions during year	–	1 529	1,529
Balance at 31 12 85	£176,768	£50 831	£227,599
Depreciation			
Depreciation at 1.1.85	17,052	201	17,253
Charge for year	2,856	–	2,856
Balance at 31 12.85	£19,908	£ 201	£ 20.109
Balance at 31.12 85	£156,860	50 630	207.490
Less Contributions received to date (see below)	103,642	50 630	154,272
N B V at 31 12 85	£ 53,218	£ –	£ 53,218
Contributions Received			
Balance at 1 1.85	85,356	49 101	134,457
Receipts	18,286	1 529	19,815
Balance at 31.12.85	£103,642	£ 50 630	£154,272

8. Investments

	£	£
Special Deposit Account	16 251	14,482
Staff Pension Fund – Special Deposit Account	21 449	73,743
	£37 700	£88,225

9. Debtors

Prepayments	667	97
V.A.T. Recoverable	1,225	1,087
	£ 1 892	£ 1,184

10. Cash at Bank

Bank Balances	37 173	27,820
Deposit/Giro 1986 Subscriptions	74 035	72,816
Less 1986 Subscription in Advance	74,035)	72,816)
	£ 37 173	£ 27,820

11. Accumulated Funds

Balance at 1.1.85	175 606	165,591
Excess of Expenditure over income for the year	3,773)	10,015
Transfer of Pension Fund monies to approved scheme	52,310)	–
Balance at 31.12.85	£109,523	£175,606

MEETINGS DIARY

All meetings unless otherwise stated are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ.

20 September 1986, 12 noon — AGM

41st ANNUAL GENERAL MEETING

The 41st Annual General Meeting of the Society will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ on Saturday, September 20, 1986 at 12 noon.

Admission is by ticket available to Corporate members only, who should apply in good time enclosing a stamped addressed envelope.

4-11 October 1986 — Congress

37th INTERNATIONAL ASTRONAUTICAL CONGRESS

The theme of the 37th International Astronautical Congress is "Space: New Opportunities for All People". It is being held in Innsbruck, Austria, at the invitation of the Austrian Solar and Space Agency.

Registration details can be obtained by writing to: 37th IAF Congress, Kongresshaus Innsbruck (Convention Centre), Rennweg 3, PO Box 533, A 6020 Innsbruck, Austria.

41st ANNUAL GENERAL MEETING

NOTICE IS HEREBY GIVEN that the 41st ANNUAL GENERAL MEETING* of the BRITISH INTERPLANETARY SOCIETY Limited will be held in the Society's Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ on Saturday 20 September 1986 at 12 noon.

AGENDA

1. To receive the Report of the Council on the Society's Affairs for the year to 31 December 1985.
2. To receive the Society's Balance Sheet and Accounts for the year ended 31 December 1985 and the Auditors' Report thereon.
3. To appoint Auditors and determine the method of fixing their remuneration. The present Auditors have expressed interest in continuing in Office.
4. To elect four Members of the Council of the Society. In accordance with Article 43 the following Members of the Council will retire at the meeting:
   A.T. Lawton, G.J.N. Smith
   Dr. R.C. Parkinson, C.R. Turner
   If the number of nominations exceed the number of vacancies, election will be by postal ballot in accordance with Article 44. The final date for the receipt of ballot papers will be 31 January 1987.
5. General Discussion.
6. Closing remarks by President.

By Order of the Council
J. L. CARTER
Executive Secretary

**Open only to Corporate Members of the Society, viz to Fellows and to Members elected before 31 December 1985. Corporate Members wishing to attend the Annual General Meeting must apply for admission tickets not later than 10 September 1986.*

A member who cannot be personally present at the meeting may appoint by proxy some other person, who must be a Corporate Member of the Society, to attend and vote on his behalf, subject, however, to the proviso that a proxy cannot vote except on a poll.

Milestones

April 1986

- **9** Exosat, European X-ray Observatory Satellite, ceased operations after 1,050 days in orbit.
- **18** US military satellite destroyed during launch of Titan 34D booster from Vandenberg.
- **23** Progress 26 unmanned freight ship launched for docking with Mir space station on April 27. Delivered fuel, food, water, equipment and mail.

May

- **3** GOES G weather satellite lost in aborted launch by Delta 178 from Cape Canaveral. Third US launch failure in a row.
- **5** Soviet cosmonauts Leonid Kizim and Vladimir Solovyov begin transfer from Mir to Salyut 7. This historic trip covered 1800 miles and took 28 hours.
- **6** French Spot 1 satellite declared fully operational.
- **6** James Fletcher confirmed as the new NASA administrator by the US Senate.
- **21** Soviets launch Soyuz TM, a modified version of the Soyuz cosmonaut transport vehicle, for unmanned test.
- **21** US National Commission on Space releases 200-page study containing plans for full-scale human settlements on the Moon and Mars.
- **29** UK Ministry of Defence announces switch of Skynet 4B satellite from Shuttle to Ariane.
- **30** Ariane 2 launch of Intelsat V satellite aborted when third stage failed to ignite.

DO YOU REMEMBER?

25 Years Ago...
6 August 1961. Gherman Titov, a 25-year old Soviet Air Force officer, spends over a day in space during the Vostok 2 mission. Titov has the distinction of being the first space traveller to suffer from space sickness.

20 Years Ago...
18 July 1966. Gemini 10 is launched from Pad 19 at Cape Kennedy on a three day mission. Astronauts Young and Collins dock with an Agena target vehicle and use its propulsion system to raise their orbit. They conduct science experiments and Collins performs a spacewalk.

15 Years Ago...
31 July 1971. The first operational Lunar Roving Vehicle is used by Apollo 15 astronauts Scott and Irwin at the Moon's Hadley/Apennine region. During three lunar excursions on this mission the rover travelled nearly 28 km.

10 Years Ago...
20 July 1976. Viking 1 lands on the Chryse Planitia basin of the planet Mars. Minutes after touchdown the first surface photo is returned showing rocks and sand close to one of the spacecraft's footpads.

5 Years Ago...
19 June 1981. Meteosat 2, an ESA weather satellite, is launched from Kourou by Ariane LO3. It reaches its intended position in geostationary orbit on 21 July.

K.T. WILSON

T 32

SPACE AT JPL

The latest news from Dr. William McLaughlin at the Jet Propulsion Laboratory in California.

Mars Observer

The Mars Observer (MO) project at JPL passed an important milestone on April 8, with the selection of the instruments which will comprise its payload. Normally, the spacecraft would then be designed to host these instruments, but the low-cost philosophy of MO dictates that the selected instruments are only candidates for flight. The payload must be tailored to match the spacecraft, and an instrument/spacecraft accommodation process is now underway. A review in September at NASA Headquarters will establish the final list.

Mars Observer, formerly designated the Mars Geoscience Climatology Orbiter (see the December 1983 edition of this column), is scheduled for a 1990 launch to Mars in order to investigate the fourth planet for one Martian year: 687 days. MO represents another step in the continuing effort by NASA to characterise Mars. Adding the MO results to those already obtained from Mariner and Viking will make Mars the best-known planet, after Earth.

The science objectives can be divided into two classes: those that address geoscience and those pointed towards climatology. The geoscience objectives are:

1. Determine the global elemental and mineralogical character of the surface materials.
2. Define, globally, the gravitational field and topography.
3. Establish the nature of the magnetic field.

For climatology, there are two goals:

1. Explore the structure and aspects of the circulation of the atmosphere.
2. Determine the temporal and spatial distribution, abundance, sources, and sinks of volatile materials and dust over a seasonal cycle.

The geoscience-related instruments consist of three types of spectrometers, a magnetometer, a radar altimeter for topographic studies, and an infrared radiometer which will be devoted to climatological studies through obtaining radiation-budget measurements and profiles of temperature, water and dust. The radio system of the spacecraft will, as usual, be shared with engineering functions and will assist climatological work through refractivity profiles of the atmosphere. It will aid geoscience with probing the gravitational field by means of orbit determination analysis.

The original conception of Mars Orbiter did not include a camera in the list of instruments. Cameras in the past have proved to be expensive, require considerable attention from the flight team to point them at their targets, and dominate the downlink with their high bit-rate requirements. However, the MO project has developed a plan to circumvent each of these three drawbacks, and a camera is on the list of candidate instruments which are participating in the accommodation process.

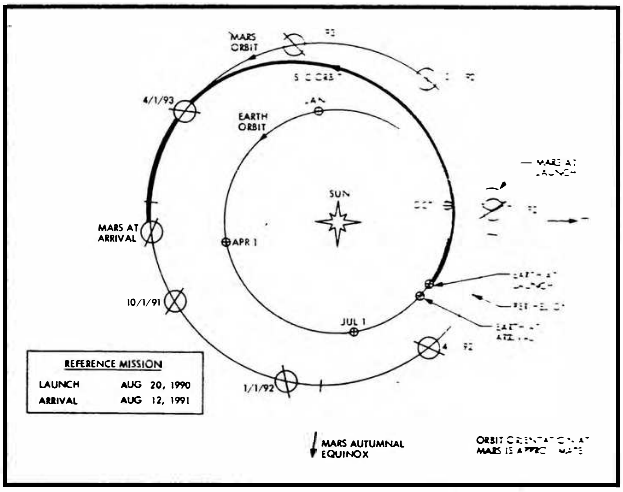
The plan is to keep the expense of a camera to a minimum by having it developed by a principal investigator, as are most instruments, rather than as a Class A facility-instrument whose functioning is deemed necessary for mission success. The camera will be bolted to the spacecraft, becoming a nadir-pointed device, so special pointing activities are not required. In fact, the spacecraft will not have a scan platform, and instrument pointing can only be done by adjustments internal to the instruments themselves. Data-rate swamping by the CCD camera will not occur since the two pictures per day will only add about 150 bits per second to the data stream. One picture will be a view of the entire planet, for synoptic and climatological purposes; the second picture will be at the other end of the resolution scale (1.4m [illegible]) to permit a detailed study of the interaction between the atmosphere and the surface and be of particular use in recording events that occur on a short time scale.

The RCA has been chosen to build the spacecraft bus, which will be of the proven Satcom-K design; one was launched into geosynchronous orbit in January to serve as a communications satellite. The spacecraft will arrive at Mars on August 12, 1991 after a one-year interplanetary cruise. Injected first into a highly eccentric orbit, MO will eventually be placed in a circular orbit at an average altitude of [illegible] km. Like that of most mapping missions, its orbit will be near polar (93 degrees).

The interplay of the 118-minute mapping orbit with the rotation period of Mars leads to a ground track that repeats exactly every 59 days. In the interim, the interleaving ground track will nearly repeat every three days; a 40 km reference swath under the spacecraft would be offset just 10 km from the one laid down three days earlier. Even in the worst case, orbital trims should be required only every two weeks.

Data will be collected continuously and placed upon the spacecraft's tape recorder for playback once per day to a 34m antenna of the Deep Space Network (DSN). Planned data rates for playback vary from eight

After launch from Earth in 1990, the Mars Observer spacecraft will have one year of interplanetary cruise before insertion into Mars orbit *NASA/JPL*

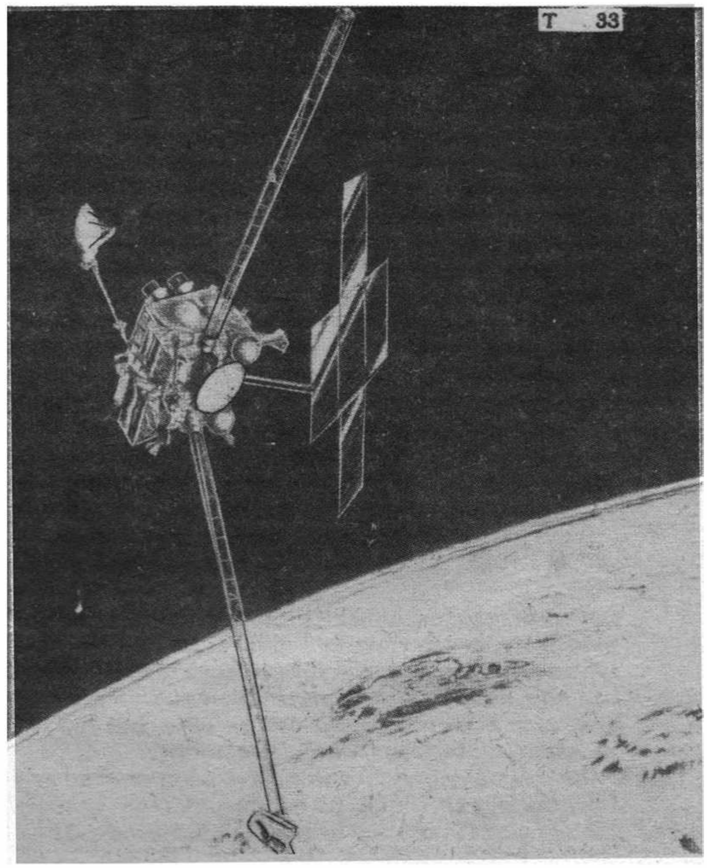


to 32 kilobits per second, depending upon the Earth-Mars distance at the time. Once every three days, direct data transmission will be done with the use of a 70m DSN antenna, primarily to accommodate the Visual and Infrared Mapping Spectrometer.

The spacecraft design calls for solar panels and a battery (the chosen orientation of the Sun-synchronous orbit produces a solar eclipse every orbit). Output for the Sun-pointed panels always exceeds 700 watts, of which 109 watts is estimated to be consumed by the payload. During a typical orbit, while in sunlight the spacecraft would consume 450 watts of power and 250 watts would be used to charge the battery. Then, for the shorter eclipse period, the batteries would deliver 330 watts to the spacecraft.

The attitude control system will employ reaction wheels and hydrazine for control, with external information coming from a Mars horizon sensor. The interplanetary cruise phase will be conducted with the aid of a Sun sensor and star tracker. Once in orbit, these devices will supplement the horizon sensor, not for control, but to obtain more accurate knowledge for the historical record of spacecraft orientation. Control of pointing is required to be within about one-half of a degree, while knowledge of pointing should be good to within one-third of that number.

The Mars Observer project is managed by JPL for NASA's Office of Space Science and Applications. The project manager is William I Purdy, to whom thanks are extended for the above information, and the project scientist is Dr. Arden Albee of Caltech.



In this artist's conception, the Mars observer conducts its mapping mission early in the next decade. *NASA/JPLCLS*

Pathfinder For Halley

When the Giotto flyby of the nucleus of Halley's comet was being planned several years ago, it was realised that a mismatch existed between the desire to fly close to the nucleus and the knowledge of exactly where that nucleus would be located. Although great progress has been made in producing an accurate ephemeris for Halley's comet (see last month's *Space at JPL*), the Giotto requirements were severe: pass about 500 km from the nucleus on the solar-illuminated side.

In 1981, the Inter-Agency Consultative Group (composed of European, Soviet, Japanese and American space agency representatives) conceived the idea of using the two Soviet Vega missions as pathfinders for Giotto.

The basic idea was simple: tie the cometary ephemeris accurately to an Earth-referenced frame. With this knowledge in hand, the ephemeris of the Giotto spacecraft, which would also be accurately known from Earth-based tracking, could be tailored to pass by the comet at the desired location.

The determination of the cometary ephemeris was a two-stage process. First, extra care was taken to construct a very accurate trajectory for the Soviet Vegas, and second, the positions of Halley's comet with respect to the Vega spacecraft were determined by use of the on-board imaging systems (optical navigation). Putting these two ephemeris efforts together yielded the desired result.

The raw materials for determining the orbits of the Vega spacecraft were three types of radiometric tracking data: doppler, which measures the spacecraft's line-of-sight velocity; ranging, which measures its distance; and Delta Differential One-way Range (△DOR), which is based upon interferometric techniques and yields the apparent angle from the spacecraft to a reference celestial source (quasars are used) as seen from Earth.

The Soviets acquired the first two types of radiometric data. Their usual tracking procedure involved taking two 20-minute passes of two-way doppler and ranging (C-band, 6 GHz) per spacecraft per week. With this tracking strategy and the orbit-determination difficulties introduced by frequent spacecraft attitude manoeuvres, the Soviets quoted an accuracy of 400 km (one sigma) for Vega. Considering that the Giotto flyby was to be within 500 km of the comet, it was clear that, if the Vega spacecraft were to act as anchors for cometary ephemeris determination, their orbits would need to be more accurately known than 400 km.

In June 1985, both Vega spacecraft flew by Venus and successfully released an entry probe and wind-measuring balloon into the planet's atmosphere. Thus, "Ve" refers to the Venus phase, while "ga", represents the later Halley phase, the first two letters of Mr. Halley's name being "ga" in terms of the Cyrillic alphabet. As part of an international network, the Deep Space Network (DSN) tracked for 48 hours the balloons that had been released into the atmosphere. The DSN also tracked the Vega spacecraft during the flyby. Both efforts consisted of acquiring △DOR data at L-band (1.7 Ghz).

DSN tracking of the Vegas continued at a test and training level after they swept past Venus and sped toward Comet Halley. In December 1985, △DOR data-taking picked up again, only to be blocked out in January because of Voyager's needs for antennas during the Uranus encounter. Then, seven △DORS

were obtained in February and three in early March. The final $\triangle$DOR for Vega 1 took place on March 3, prior to its March 6 encounter with Halley's comet. For Vega 2, the corresponding dates were March 4 and March 9.

The $\triangle$DOR data were processed at JPL and then forwarded to the Soviets. Both JPL and the Soviets independently determined the Vega orbits using the $\triangle$DOR data. The Soviet on-board optical data and JPL's Vega orbit solutions were sent to the European Space Agency. Within 48 hours of receiving the Vega 2 data, the Giotto navigation team predicted the comet's location at the time of encounter and executed the final targeting manoeuvre.

The final orbit determination for the Vega spacecraft was accurate to about 40 km (one sigma). This enabled Giotto to be aimed with confidence at 540 km from the nucleus – 500 km plus the one-sigma safety margin. Preliminary indications place the flyby point of Giotto at approximately 600 km from the nucleus, and the high-resolution images it captured are safely tucked away in the history books, due in part to a good exercise in international cooperation.

Thanks are extended to Jordan Ellis, the Deputy Technical Coordinator for Pathfinder/JPL., and Dr James F. Jordan, the Project Manager for Pathfinder/JPL., for conversations on the subject.

A Seti Experiment

One of the most difficult problems facing those who search for extraterrestrial intelligence (SETI) is how, where, and when to look for evidence of ETI. The subsequent problems of interpretation and response to any such evidence would not be easy, but the first problem – detection – clearly has priority.

Of the many methods that have been devised as to how the search should be conducted, radio searches for signals of intelligent origin have achieved the most prominence and have most often served as the method of choice by practitioners.

Common to many search strategies is a preference for the region near 21 cm in the radio spectrum; it features several interstellar emission lines which may have symbolic value with regard to the chemistry of life. That is, searches near 21 cm are predicated on a precontact convention which, it is hoped, the sender will also recognise and participate in for the purpose of increasing the probability of contact.

The question of where to search has been answered in two fundamental ways: search the whole sky or search Sun-like stellar systems only. The former method partakes of the classic astronomical technique of the all-sky survey, while the latter concentrates resources on targets felt to present a higher *a priori* probability of success and thus resembles, in intention, the 21 cm convention. The all-sky survey and the targeted search have both been integrated into the NASA SETI programme described in the April edition of this column.

To the question of when to search, one might be tempted to answer "whenever it proves convenient." But the parameter of time represents a degree of freedom that might be used in some way as a convention, increasing the probability of contact.

In order to employ time, one needs a clock, and that clock must be accessible to Receiver (us) and Sender alike. A candidate that fills this requirement is supplied by the astronomical phenomenon of a nova. They are visible for thousands of light years and do not (as a class) "tick" too frequently as to be confusing nor too rarely as to be unuseful – a bright nova is visible to us about every 25 years on the average.

The use of novae as SETI clocks was described by your correspondent in *Icarus* in 1977 (vol. 32, 464-470) and is scheduled to appear in some detail in the July issue of ***JBIS Interstellar Studies***; so, only the rudiments will be discussed here.

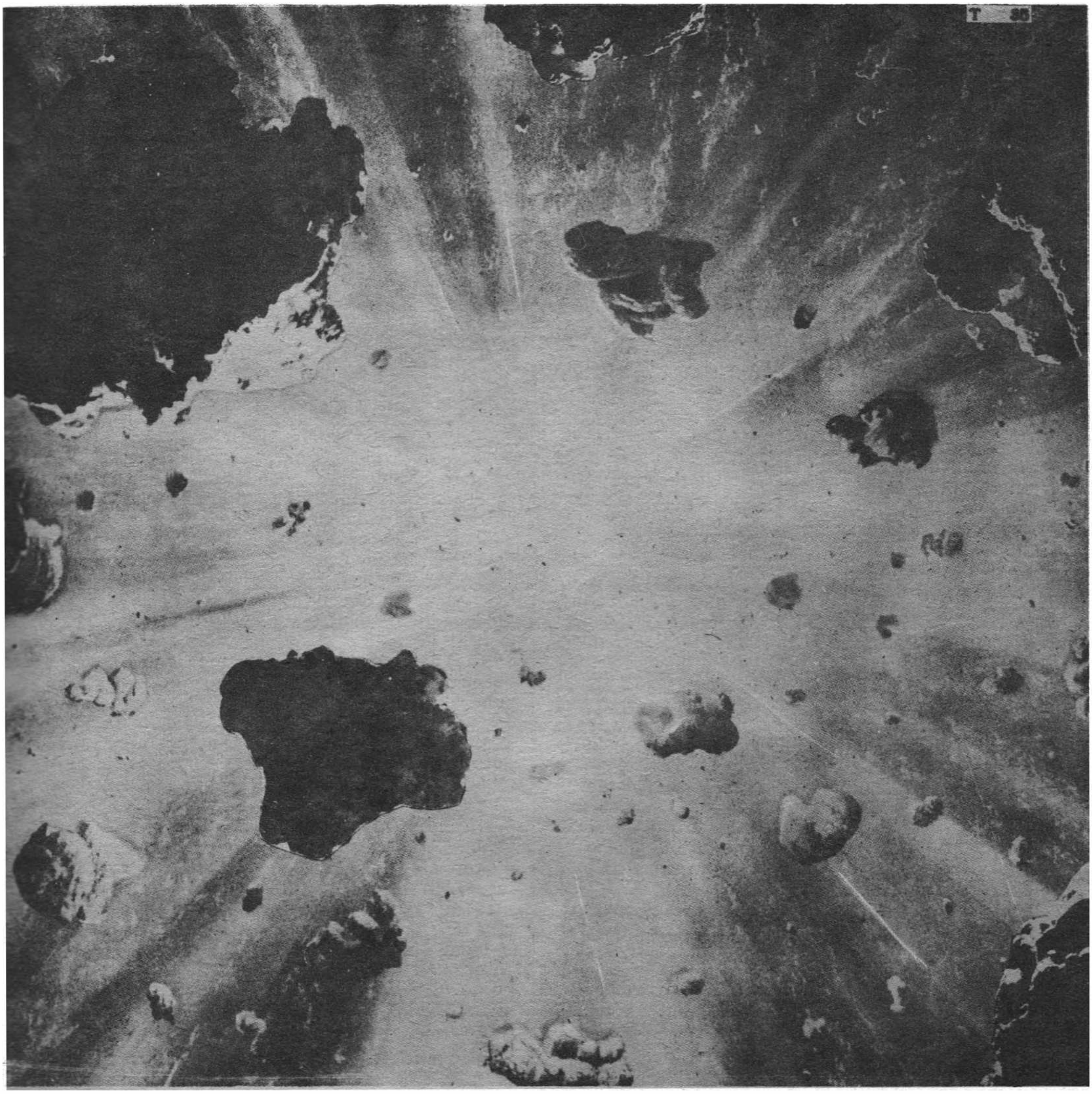
How is the owner of such a clock to use it? Because the velocity of light is not infinite, Sender and Receiver will usually perceive the nova explosion years apart, and the signal itself will take years to travel from Sender to Receiver. Hence, some calculations are required. The principle upon which these calculations are based is that Sender emits a signal upon first sight of the nova; this is the clock convention (a second possible convention is discussed in ***JBIS***). It is the responsibility of Receiver to undertake the calculation of the time in which the signal will be received, at Earth for the case of interest. The calculation only depends upon the speed of light and the relative geometry of nova, Sender, and Receiver. The value of the clock depends upon how accurately this estimate can be made; for stars near the Sun, an accuracy of a few months is typical. The comparison of these months to the 25 years or so between "ticks" indicates the focusing power of the timing convention.

A cosmic clock struck in the summer of 1975 when Nova Cygni became visible in our skies. Calculations show that if a Sender were located in the Tau Ceti system, some 11.8 light years from us, and sent a signal according to the clock convention, we would observe the signal at the start of 1987. The uncertainty in this estimated time is about four months (one sigma), due to our uncertainty in the distance of Tau Ceti. Under similar assumptions, a signal could be received from the Epsilon Eridani system in the middle of 1988, with an uncertainty of about two months.

The Sun-like stars Tau Ceti and Epsilon Eridani have figured before in the history of SETI. They were the two systems observed by Frank Drake in his pioneering SETI experiment, Project Ozma, for three months in 1960.

The view was espoused in last month's column that most extraterrestrials would be greatly in advance of us. The present SETI experiment seeks contact with two Sun-like systems under a rather anthropocentric set of assumptions. The reconciliation of these positions comes through considering the search as similar to an experiment in animal psychology, with us as the cooperative subjects of the experiment. With luck, we will come under the scrutiny of the analogue of a graduate student working to complete a thesis on "The response of *Homo sapiens* to timed radio signals." Copernicus taught us not to be too proud.

My colleague, Mr. Michael F. Gilmore, has kindly consented to act as coordinator for this experiment, and questions concerning techniques or strategy of observation should be addressed to him at M3/2544, TRW, One Space Park, Redondo Beach, California 90278, USA.



The interior of a comet looking down towards the Nucleus. *Julian Baum, Science Photo Library.*

Gravitational Sculpture

Gravity is something that we have learned to live with in a sometimes uneasy partnership. Balloonists neutralise it, engineers conquer it, trapese artists defy it, and the rest of us just stumble about in it. When the Apollo astronauts walked on the Moon, they showed remarkable skill in quickly adjusting to a new gravity environment.

Our intellectual relationship with gravity has its roots in the researches of Galileo, Kepler, and Newton in the seventeenth century. Much of this tradition has been carried to the present day in the subject of celestial mechanics and its space-age companion, astrodynamics.

Until the use of electromagnetism in the last half of the nineteenth century and particle physics and relativity in our century, celestial mechanics held almost absolute dominion over our understanding of nature. Chemistry, biology, and geology tried, with mixed success, to emulate the mathematical precision with which celestial mechanics ordered the universe. The culmination of this enthusiasm was expressed by Laplace (1749-1827) who believed that if a super-human intelligence could grasp the positions and velocities of every particle in the universe and the forces acting upon them, then "nothing would be uncertain and the future, as the past, would be present to its eyes."

Astrodynamics is the study of the motion of spacecraft and derives many of its ideas from celestial mechanics. Two special emphases give astrodynamics a particular flavour, distinguishing child from parent. First, astronomical objects infrequently pass close to one another, while spacecraft, guided by human curiosity, are often found close to gravitating bodies: planets, satellites, comets. This results in different dialects of mathematics being developed in the two disciplines. When atmospheric drag is included, the dialect becomes another language. Second, spacecraft are dynamically messy. They emit propulsive gases, drop off parts while in flight, and unexpectedly reorient themselves.

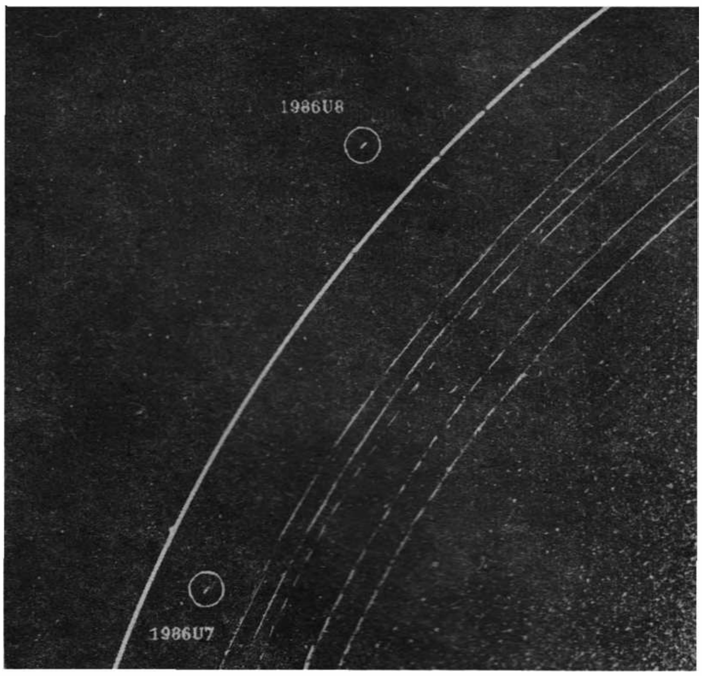
Astrodynamics is a subject with an enormous literature, but a subset of considerable importance to spaceflight can be identified – the deliberate use of gravitation to shape trajectories in a way to accomplish some special purpose. The metaphor "gravitational sculpture" may not be too ambitious to describe the effort, which thrives upon the closeness relation between spacecraft and gravitating body mentioned above.

A sculptor needs materials, and Kepler supplied one of the most important for astrodynamics: the ellipse. Building upon his work concerning the orbit of Mars, Kepler showed in his *Astronomia Nova* (1609) that all of the planets move about the Sun in ellipses, with the Sun at one focus.

When a spacecraft orbits a planet, it too travels (nearly) in an elliptical path. Gravitational sculptors have learned to control this path in numerous ways to meet their goals. One of the best-known techniques matches the period of time in which a satellite circles the Earth with the rotational period of our planet. The result is a keystone of the telecommunications industry: the geosynchronous satellite hanging about 36,000 km above the Earth. The orbit is often called the "Clarke orbit" after former BIS President Arthur C. Clarke, who championed its use in 1945.

Another common manipulation of Kepler's ellipse is to move in some optimal way the orbit plane in which the ellipse lies. For example, the Infrared Astronomical Satellite (IRAS) moved in a Sun-synchronous orbit about the Earth; the motion of its orbit plane was contrived to advance at the same rate that the Earth moved about the Sun in its yearly circuit. Thus, for 300 days of operation in 1983, the orbit plane of IRAS was always more-or-less perpendicular to the Earth-Sun line, keeping the radially-pointed cooled telescope well out of harm's way from solar interference. Such motion of an orbit plane is actually powered by the equatorial bulge of the Earth, and the rate of motion can be controlled by adjusting the parameters of the satellite's orbit, particularly its altitude and inclination to the equator.

Voyager 2 discovered two "shepherd" satellites associted with the rings of Uranus. They are seen here on either side of the bright epsilon ring.



A lesser-known masterpiece of the gravitational sculptor's art is the "frozen orbit." Consider the orbit plane as described above. In addition to the motion of this plane, the ellipse lying in it normally rotates in a slow, but continuous, fashion. However, by a proper choice of orbital parameters, it is possible to stop or reduce the rotation of the ellipse in its orbital plane, "freezing" it in place or forcing it to oscillate slowly in pendulum fashion about one location. Of course, the satellite continues to move around the ellipse like a bead on a wire, but the satellite-to-Earth relation is more nearly constant during each orbit, which may be of benefit for certain measurement applications.

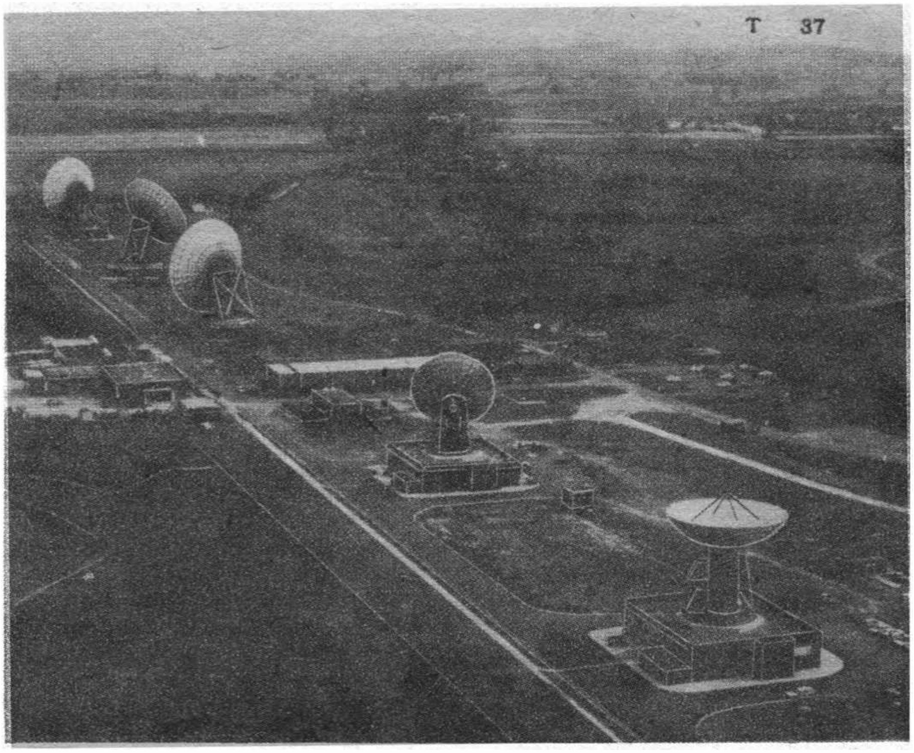
The Michelangelo level of gravitational sculpture is reached in the gravity assist, first employed in the Mariner 10 mission to Venus and Mercury (1973 launch). Imagine a spacecraft approaching a planet and just missing it, passing behind the trailing limb of the planet as the latter speeds along in its orbit. It is not difficult to see that the gravitational tug, minute as it is, exerted by the spacecraft on the planet will slightly slow the planet's motion as a result of this near miss. Since nature seems to want to be fair about such things, the laws of mechanics require that the spacecraft receive an increase in speed. Herein is born the gravity assist. Other trajectory-shaping goals, such as bending in a certain direction, can be met by appropriate choice of the spacecraft aim-point with respect to the planet's limb. The gravity assist has made possible the rapid exploration by Voyager of four different planets – Jupiter, Saturn, Uranus, and Neptune – in only 12 years of flight. The ICE encounter with Comet Giacobini-Zinner in 1985 was also enabled by earlier gravity assists within the Earth-Moon system, and Galileo may be speeded on its way to Jupiter by a gravity assist from Earth itself encountered two years after launch as a result of looping back, trading time for velocity. The planned satellite tour of Jupiter by Galileo is made possible by the gravity-assist concept.

Before we get too puffed up with our cleverness, the accomplishments of Nature in this arena should be recognised. Some of the [illegible] narrow rings in the Saturnian and Uranian ring systems have been shaped by the gravitational [illegible] of nearby shepherding satellites. Then, there are the [illegible] gravitational forces of the Sun and Jupiter which hold the Trojan asteroids in place. Sufficiently strong gravitation can even produce effects on light. The "gravitational lens" focuses the light from distant matter by means of a massive object interposed between that distant matter and us. Sometimes these lenses can make one distant quasar appear as two or more. The phenomenon provides a means to estimate the mass of the intervening object. Recent reports have disclosed that one such gravitational lens may be the most massive object yet discovered by astronomers, surpassing the mass of our entire galaxy by a factor of perhaps ten thousand!

MADLEY SATELLITE EARTH STATION

Robert T. Bowden

The world's intercontinental telephone network has, for two decades now, enjoyed the fruits of Arthur C. Clarke's unique concept of geostationary communication satellites and, in the last ten years in particular, the dependence upon communication using this medium by countries of the global community has become awesome. In the United Kingdom, British Telecom International (BTI), formerly the Post Office, has always carried the responsibility for this service and until very recently had an exclusive access to the available space segment. Although in the UK this access is now shared with a second telecommunications entity, it is nevertheless the case that virtually all of the UK's International public service telephony traffic is carried by BTI facilities.



Madley Earth Station Site from the air, showing 2 Intelsat Standard C antennas in the foreground and 3 Intelsat Standard A's at the other end of the site.

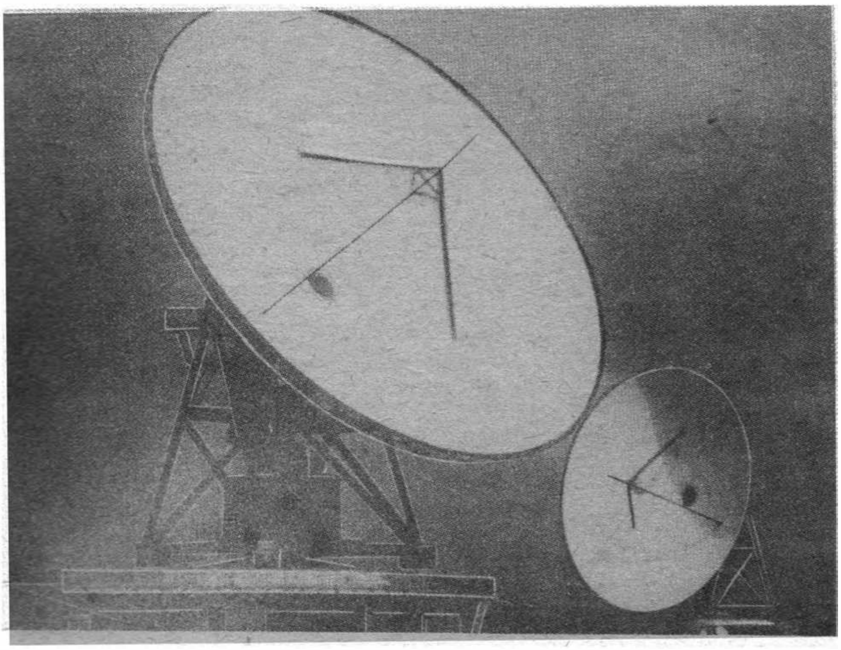
Until 1978 only one main Earth station was operational in this country – the well known complex at Goonhilly Downs in Cornwall. However, early in the 1970's it became clear that to have so much of our satellite communication capability in one location was unwise, particularly in view of the huge predicted growth of traffic for that decade, and as a consequence planning began for a second main Earth station. After a difficult and some times frustrating search, the Satellite Division of BTI acquired part of the abandoned airfield at Madley, six miles west of the city of Hereford, which appeared to satisfy the difficult set of criteria which had to be met. Thus the embryonic development of Madley Earth Station commenced and its growth has been virtually continuous, until today it has become probably the largest modern facility of its kind in the world.

Madley's Suitability

The optimum siting of an Earth station depends upon a number of factors most of which are met by the Madley location:

1. Low levels of potential interferring radio signals and general electrical "quietness".
2. Natural screening from distant microwave sources which might interfere under conditions of anomolous propagation - at Madley the Black Mountains and Malvern Hills form excellent natural "barriers".
3. Geologically sound to provide stable foundations for large structures.
4. Geographically convenient, both from a road access point of view and to permit access to the inland trunk transmission network – which conveys the traffic signals back to the International Switching Centre (ISC), located in London.

Madley Earth Station – Antennas No. 1 and 2 looking at Indian Ocean and Atlantic Ocean satellites respectively. No. 2 is in the foreground. Both are conventional wheel and track designs with sector gears for elevation movement.



An important addition to the above is the need for the local population to be sympathetic to the requirements of international transmission and accept the presence of rather large dish antennas in their locality.

In countries like Britain, this final factor can be the one which ultimately determines the degree to which the first four can be satisfied. The fourth criterion above has a considerable economic impact and would normally make a location close to London the most desirable. However, the discovery and acquisition of a suitable, interference free site of 50-100 acres in the vicinity of London is extremely unlikely.

After options on the Madley airfield site had been obtained – coincidentally it was a Signals Training School during World War 2 – a favourable response was soon received from the local planning authority for a six antenna complex. This permitted a start to be made and the first antenna, a 32m diameter Intelsat Standard A, went into operation in October 1978 after several years

Earth Station

of intense activity to provide site services of various kinds including accommodation and buildings to house the radio equipment, power generation, maintenance workshops and welfare facilities. In addition a new team of experts had to be recruited and trained with only a small staff contribution available from the sister station at Goonhilly.

Radio System Configuration

For those not familiar with satellite operational techniques, two main frequency bands are in use at the Earth station for common carrier international systems. These use 6 GHz for transmit and 4 GHz for receive (C Band), and 14 GHz transmit and 11 GHz receive (Ku Band).

The modulated up-link carrier will be carrying traffic for several destination countries, each of which must receive and demodulate the translated signals from the satellite and only select those parts of the transmission baseband which are destined for them. Conversely, the distant countries transmit carriers to the satellite which must all be received at the UK ground station. As a result the receivers in use with a particular antenna will outnumber the transmitters by typically ten to one.

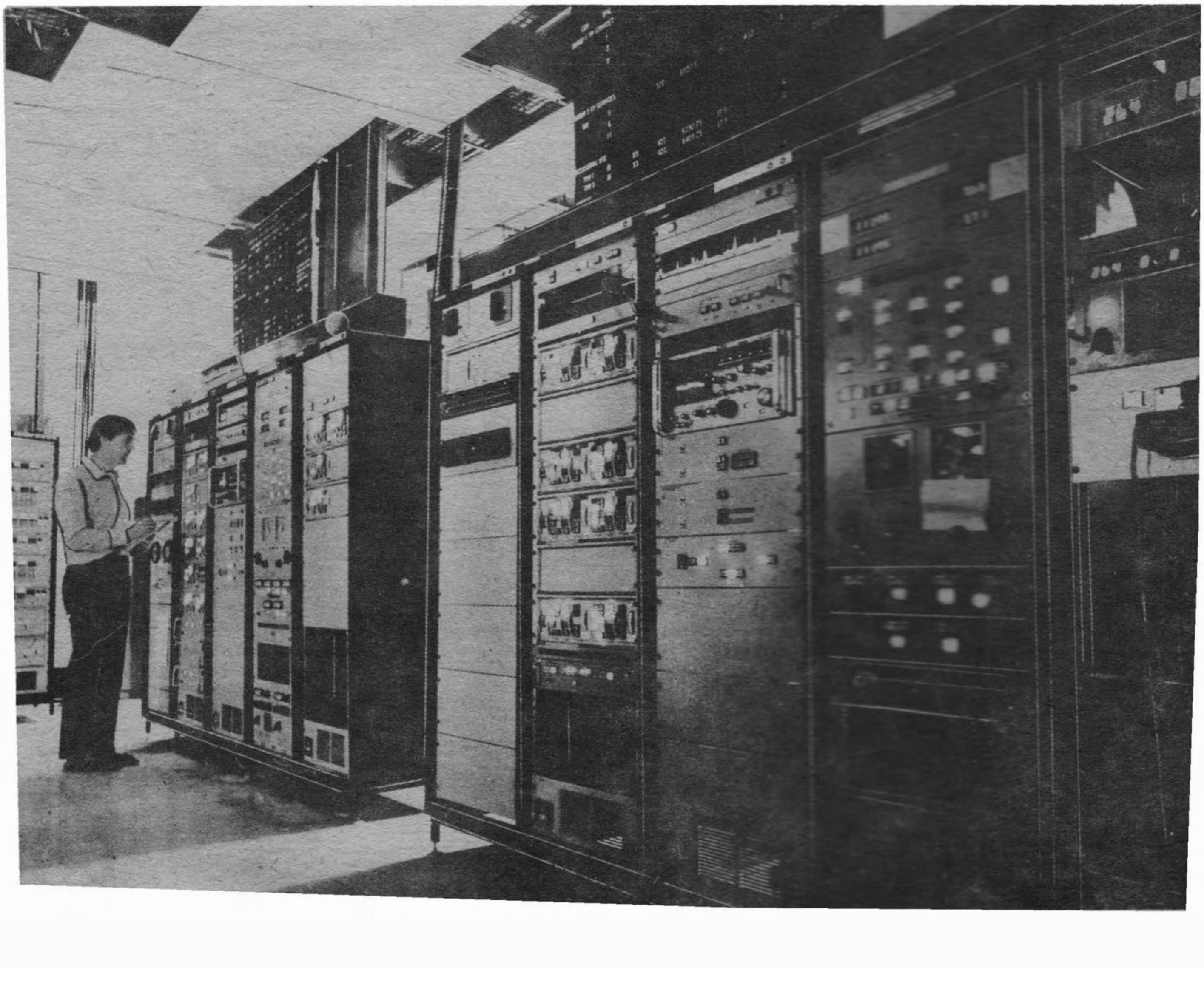
A much simplified schematic of the radio equipment associated with one antenna is shown in Fig.1. Telephony channels emanating from the ISC in London are assembled (Multiplexed) into basebands and each baseband is used to frequency modulate a 70 MHz carrier. At this frequency the transmit signals are conveyed across site to the antenna base building, where they are converted up to the transmit frequency in the 6 GHz band by two stages of translation. The low level microwave signal is then amplified by intermediate (IPA) and high power (HPA) amplifiers before being presented to the transmitter coupling matrix and feed assembly and finally the dish surface for outward transmission. This now conventional method of assembling signals for use with the satellite is called Frequency Division Multiple Access (FDMA).

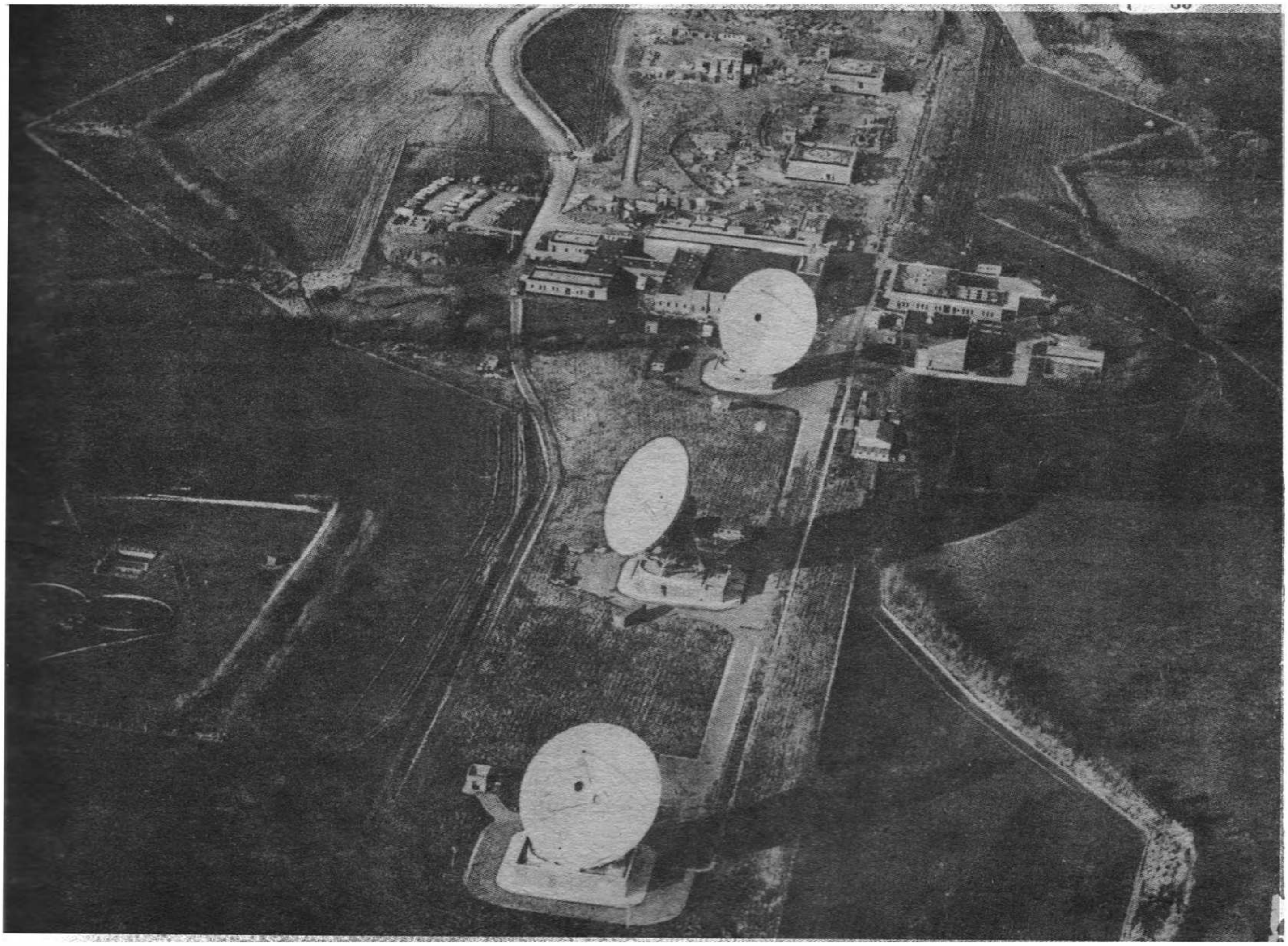
The receive band of signals from the satellite at 4 GHz is at a very low level and requires substantial amplification using first a low-noise amplifier (LNA) – usually a cooled parametric type, although such expensive devices are now becoming less essential – followed by a post-LNA amplifier. This provides a signal level high enough for the whole band of received carriers to be conveyed on waveguide across site from the antenna to the main central building, housing the receivers, usually two per received carrier which are fed via multiway splitters.

The received basebands are demultiplexed and the [illegible] channels corresponding to those transmitted are sent back to the ISC [illegible] microwave or coaxial [illegible] Television signals fo[illegible] path although only one TV channel can be used per carrier [illegible] does not apply.

The transmitters [illegible] in use in Madley [illegible] but mainly use [illegible] one per carrier [illegible] RF output powers of [illegible] the 6 GHz band. [illegible] nearity is required [illegible] made to amp[illegible] Travelling Wave Tubes [illegible] provide similar [illegible] but can be used [illegible] carrier applications. [illegible] ers in the [illegible] versions of the [illegible] on the basis of [illegible] where they are

Madley Earth Station – A view of one corner of the Operational Control Area, showing transmitter control and antenna steering racks associated with 2 Standard A systems.





Madley Earth Station Site from the Air showing 3 Intelsat Standard A antennas in the foreground with construction taking place on 2 Intelsat Standard C antennas at the top of the picture.

essential because of the multi-carrier requirement.

The power gain of high power Klystrons or TWT's is similar and of the order of 35-45db. It is interesting to note that the march of progress in satellite design has gradually whittled away at the uplink power required and typically the biggest size carriers (TV or 1,200 channel telephony) will only require that the HPA provide 200-300 W of power to the antenna feed.

Present Operational Status of Madley

The first operational antenna at Madley took over the Indian Ocean Region Primary (IOR/P) service from Goonhilly. The satellite orbital position used is well to the East and, at Goonhilly, had resulted in an antenna elevation angle close to the minimum acceptable of five degrees. The one or two degrees increase resulting from the move to Madley was worth having – particularly as this satellite path was showing a very high predicted growth in traffic and hence received carriers

Within 18 months Madley 2, another Standard A antenna, was nearing completion and this came into service in March 1980. This was used to a new Atlantic satellite designated Major Path Two (AOR/MP2), as by this time the transatlantic traffic had grown to a level where three satellites were essential to cope. In general "Primary" satellites carry traffic from all the Ocean Region users including the very small countries having only a few channels of capacity. To cater for the large traffic capacity of "thick-route" users such as UK, USA, France, Canada, W.Germany etc., it became essential to provide major path satellites in the Atlantic Region from early in the 1970's.

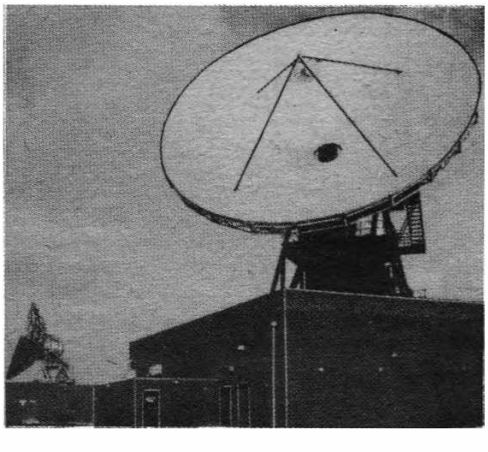
Within two years of Madley 2 service, a third Standard A was completed and this took over yet another new satellite path – IOR/Major Path, as by this time IOR traffic to Japan, Australia, India and Hong Kong had reached thick-route levels.

The last two years has seen the provision of two 19m diameter Intelsat Standard C antennas, for use with the (relatively) new Ku frequency bands. Aerial 5 is used with the Ku band transponders of the AOR/MP1 Intelsat V satellite and carries mainly large capacity carriers to North America. Aerial 4 is in use with the new European Regional satellite – ECS1/Flight 2.

This latter satellite was designed from the outset to carry telephony in the form of digital signals using a system of Time Division Multiple Access (TDMA), whereby a burst of traffic data is transmitted from each ground station sequentially to the satellite every 2ms. This technique has also been put into service on Madley 2 for use to North America and Canada, and digital transmission will form the main thrust of technology change over the next decade, as the present FDMA telephony carriers are replaced by TDMA traffic bursts in other transponders of the same satellite.

While the technology exists to digitise television signals, so much of the national network and studio equipment is geared to the use of conventional analogue signals, it seems that

Madley Earth Station – Antennas 4 and 5, both 19m diameter Intelsat Standard C systems. Both use wheel and track for azimuthal movement and sector gears for elevation.



digital satellite TV for use operationally is still some way off – although the superior performance in terms of signal-to-noise ratio of digitised video has long been acknowledged by the broadcasters.

Television traffic is now a major source of satellite utilisation and Madley has a well equipped TV control room to cope with the frequent multiple trans-missions for news and special events. In addition, satellite double-hop connections of TV are possible since the propagation delay (about 250ms per hop) is not a problem as long as the sound channel is conveyed over the same path as the video, or suitably delayed electronically.

Madley Operations Control Area – showing some of the antenna control racks and monitoring consoles in the background, and an engineer carrying out TDMA System monitoring using a VDU presentation.

Madley Operational Philosophy

The operation of a modern satellite Earth station is a highly dynamic "real time" activity. Gone are the days when service can be sacrificed in the cause of technical development or research. The global satellite network now forms a highly integrated machine – constantly growing – which must adapt readily to a multiplicity of customer demands for telecommunication facilities.

Reliability is a key word and an example of this is the need to design antennas which are not only extremely rugged but have subsystems such as tracking/steering, servo drives and feed assemblies which can go on working for many years with a minimum of attention. Such reliability does not come cheaply but the money is well spent – typically system availability exceeds 99.99 per cent throughout the year.

Madley represents a perfect example of modern applied high technology. The electrical and electronic equipment associated with each of the five antennas presently in service represent state of the art, and no corners have been cut or design targets sacrificed in a search for low cost alternatives. The large quantity of equipment requires a highly organised approach to maintenance and this is carried out by a group of technicians and engineer managers on day duties who perform in-depth fault diagnostics and repair. The hour by hour operational changes, first line action and status monitoring is carried out by a team of shift technicians, who ensure the on-line status of the station at all times of the day or night.

The technical capability of the staff requires to be high and tends to produce a man who, irrespective of age, retains an enquiring and interested approach to his work. Inevitability, in such an environment, the application of computer methods to many areas of the station has taken place and, for certain new digital systems such as TDMA, they are an extremely powerful tool in the diagnosis of complex faults occurring on equipment carrying digital telephone traffic at rates of 120 Mbit per second.

Unlike many overseas Earth stations, Madley is largely self contained in all support and peripheral areas of activity. This is perhaps not the cheapest way of running the station but does have the advantage of producing an integrated team who, whether door-keeper or senior manager, contribute to the stations activities with a sense of continuity and belonging.

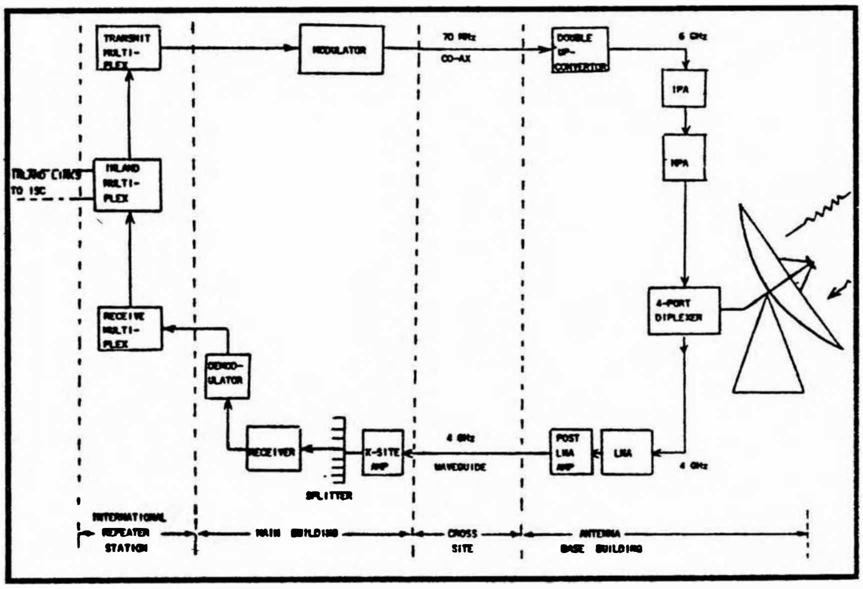
The Future

To predict the growth of the Global and Regional satellite networks beyond this decade is not easy. Applications are constantly being devised which exploit the unique advantages of satellites such as flexibility, proven reliability and relatively stable space-segment costs. To what extent the fibre optic trans-ocean cable systems pose a future threat is hard to ascertain, but no doubt the buoyant North Atlantic "thick" routes will provide some interesting battles on tariffs when the new cables arrive. It is certain that many land-locked countries will always need access to satellites for their external communications needs, and the growth of mobile systems (maritime, land and aeronautical) promises a whole new realm of activity for the future.

Although Madley has almost reached a point of "hold" relative to the momentum of previous developments, it is quite probable that this is only temporary. The world community has a growing need for intercommunication between people and in its own special way Madley and its staff will always be doing its best to meet that need. Madley has come a long way in the last eight years and the way ahead looks well endowed with interest and challenge for the privileged team in this most pleasant part of Herefordshire.

Madley is not generally open to the public but readers may wish to note that organised parties are always welcome to visit by prior appointment and will be assured of an interesting tour of the facilities. Application should be made in writing to: The Earth Station Manager, Madley Satellite Earth Station, Stone Street, Madley, Herefordshire HR2 9NH.

Fig. 1. Madley Earth Station, signal paths associated with a typical C-band antenna.



SEPT/OCT 1986 £1.25

Spaceflight

The International Magazine of Space and Astronautics

CONTENTS

Editor:
G. V. Groves

Assistant Editor:
C. A. Simpson

Managing Editor:
L. J. Carter

Spaceflight Sales:
Shirley A. Jones

Advertising:
C. A. Simpson

Spaceflight Office:
27/29 South Lambeth Road,
London. SW8 1SZ. England.
Tel: 01-735 3160.

DISTRIBUTION DETAILS

Spaceflight is available world-wide by annual subscription. The rate for 1986 (10 issues) is £30.00 (US$50.00) inclusive of surface mail delivery. Subscribers also receive the publication *Space Education* (two issues) at no extra charge.

Back issues of ***Spaceflight*** are supplied from available stocks at £2.00 (US$4.00) each, inclusive of surface mail delivery.

Spaceflight may also be received regularly by mail through membership of the British Interplanetary Society. Details of application are available from the Executive Secretary.

* * *

Spaceflight is distributed in the UK through newsagents by: Profile Books Ltd., 1 Pontiac Works, Fernbank Road, Ascot, Berks SL5 8JH. Telephone: 0344-884222. (If you have difficulty in obtaining your copy of ***Spaceflight*** please notify Profile Books, Circulation Manager (at Ascot) in writing, stating the name and address of the newsagent).

* * *

Published by the British Interplanetary Society Ltd., (No. 402498). Registered office: 27/29 South Lambeth Road, London, SW8 1SZ, England.

Vol. 28 Nos. 9/10 September/October 1986

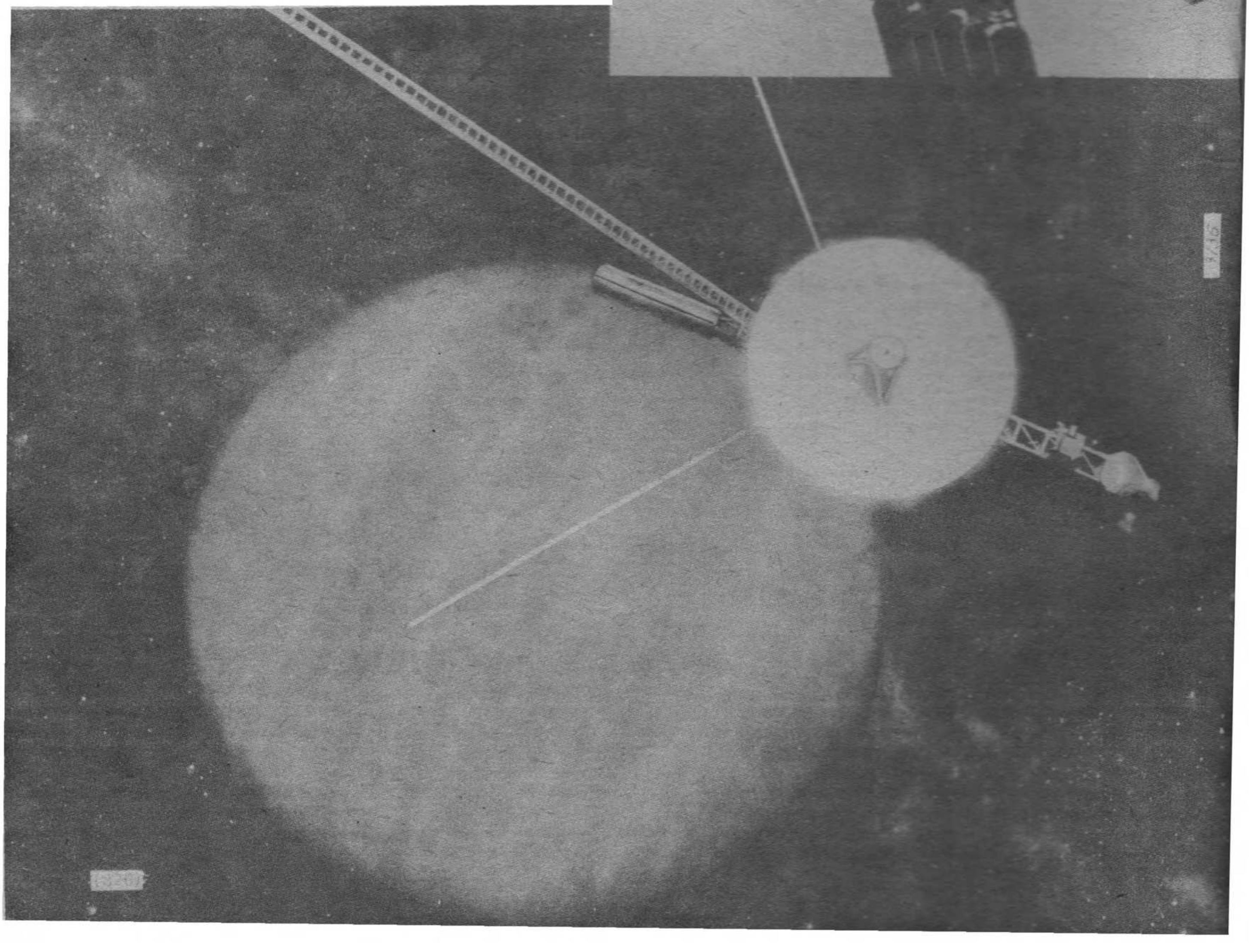
Front cover: Detailed studies on the feasibility of the French proposal for a mini-shuttle, called Hermes, which would be launched atop Europe's planned Ariane 5 booster are due to get underway this autumn. Final go ahead for the programme could be given by ESA member states next summer. The artist's impression shows the Hermes craft after reaching low-Earth orbit on a space station service mission. More details on page 333.

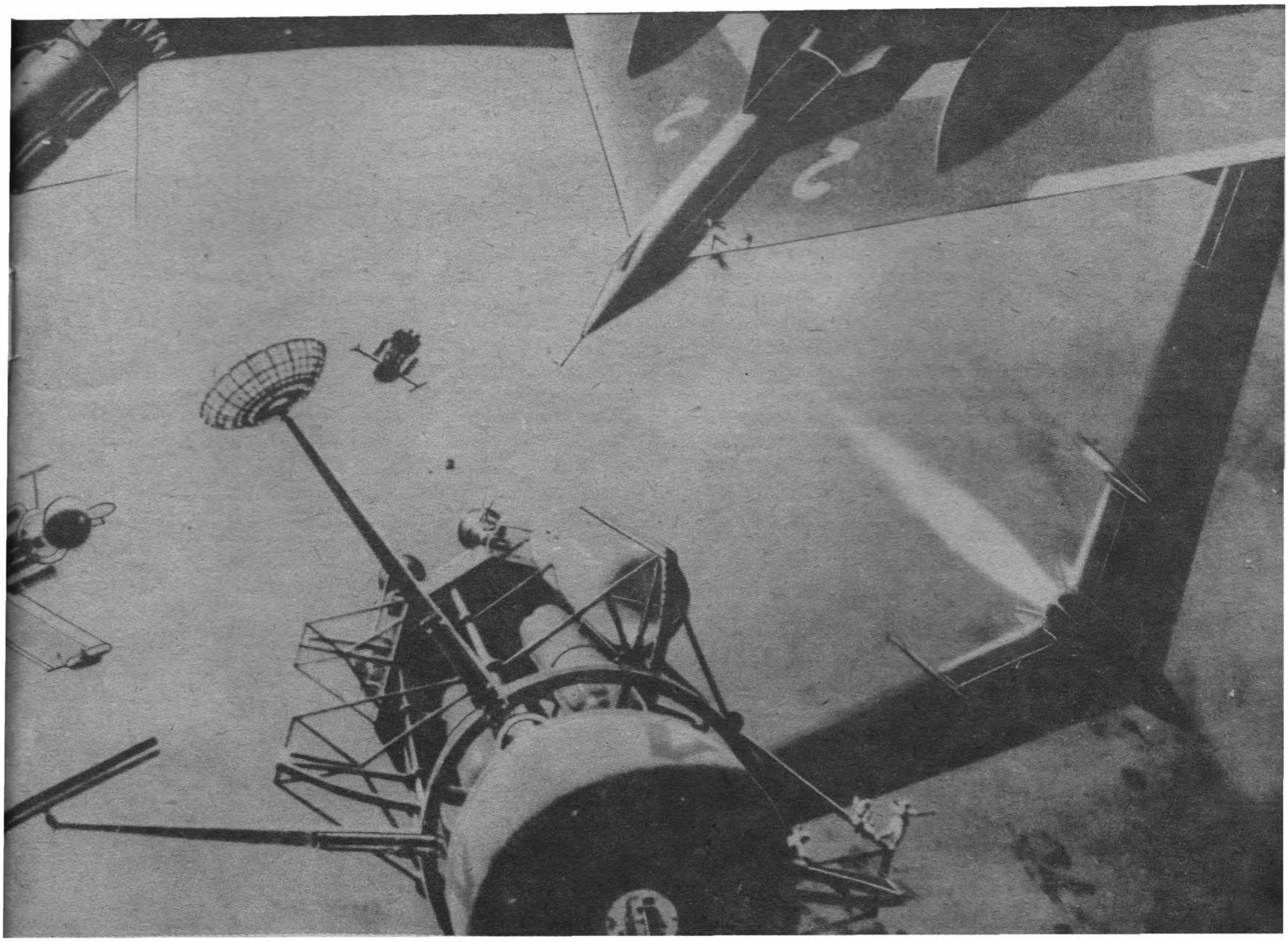
VISION and REALITY
– in the Conquest of Space

Earth-bound telescopes first revealed the mountainous landscape of the Moon – but only so far, being limited by optical conditions. Exploration of the lunar surface continued in other ways – in creative minds finding expression through astronomical art – until the technology of the Apollo programme brought about a new reality. Such events are characteristic of man's exploration of the Universe – a sequence of imaginary leaps and technical breakthroughs. Vision and reality do continually interact.

Artist Chesley Bonestell inspired a whole generation of young scientists and engineers to explore the realms of outer space through his paintings of Earth-orbiting space stations, rocket vehicles on Mars and vistas of Saturn and other planets. In 1955, before the dawn of the Space Age, he was portraying the settlement of Mars. In the picture on the right he shows the assembly of the first of three landing craft in Mars orbit.

Just as the vision of space has preceded the reality so the reality has also helped to create the vision. The Voyager 2 spacecraft after its encounter with Uranus on January 24, 1986 is now on course for a close encounter with Neptune. Its arrival in August 1989 is the subject of the painting below by Julian Baum which shows Voyager 2 on target for a flyby of Neptune's north pole.





Who Needs Space Artists?

by David A. Hardy

The first astronomical artists I encountered were the Society's own R.A. Smith, in Arthur C. Clarke's early books, and Chesley Bonestell,* in The Conquest of Space, all around 1950. At the age of 14, they made a big and lasting impression. Many of today's leading scientists, writers – and artists – were similarly influenced, and there can be no doubt that those early illustrations played an enormous part in making space travel a reality.

My own work was first published professionally in 1954 (in a book by Patrick Moore); previous to that it had been seen publicly only in exhibitions organised by the Midlands Branch of the British Interplanetary Society.

For many years, the number of active space artists could be counted on one hand. And whereas at first they had only their imaginations to draw upon, enhanced by the observations of astronomers and the plans of engineers such as Wernher von Braun or Ralph Smith himself, from 1957 onward the information pouring in from outer space enabled and also demanded greater accuracy in depicting scenes and hardware.

I am delighted to be able to call myself a 'first generation space artist' – just – because I was illustrating three years before the dawn of the so-called Space Age, when Sputnik was launched. However, my lifelong interest in astronomical art has revealed that there were artists depicting the landscapes of other worlds long before Bonestell.

In 1874 a book was published entitled *The Moon*, by Nasmyth and Carpenter. Apart from advancing a rather unique theory of crater formation, in which lava fountains from a central peak produced the ringwall, which I well remember from discovering the book in my local library as a schoolboy (not in 1874!), it contained a number of beautiful plates of lunar scenes. Most of these were actually plaster of Paris models, correctly lit and photographed. Although these had a somewhat eroded appearance, which may have been due to the nature of plaster, the mountains were rather steeper and more jagged than we now know to be the case.

The Abbé Moreux also produced some interesting examples around the turn of the century, and worked on the two-volume *Splendour of the Heavens,* which was published in 1927, as did H. Sepping Wright and Scriven Bolton (another model-maker). Although their work is beautiful in its own right, all tended to over dramatise lunar landscapes. And whilst Bonestell's paintings are truly works of art, despite his constant claims that they are only illustrations (and many would

*See obituaries on page 355

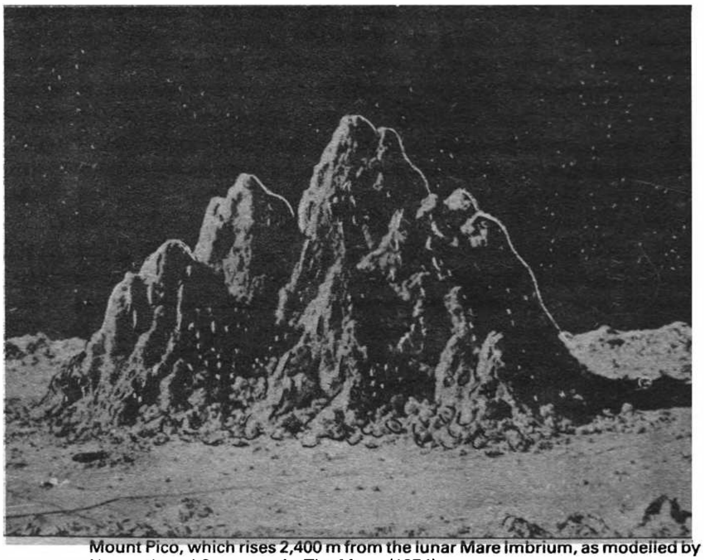
say that the Moon *should* look like that), there is no doubt that his dramatic, uneroded peaks now look a little 'over the top' ...

Getting It Right

The artist who got it most nearly right was a Frenchman who was also a writer: Lucien Rudaux. In the 1920s and 30s, he illustrated books such as his own *Sur Les Autres Mondes* (1937), in which he depicted gently rounded mountains and lava plains which look remarkably like Apollo photographs. As an observer, he often concentrated on the Moon's limb or edge, where a good magnification reveals the true shape of lunar ranges. A crater on Mars has now been named after him; in 1985 as asteroid discovered by Eleanor Helin of JPL and previously unromantically called (3129)1979MK2, was named 'Bonestell'. (Lunar craters are of course only named after deceased persons, as Chesley pointed out, at the age of 98, only shortly before he died on June 11, 1986.

Artistic Interpretation

Today, in 1986, we have received back images from all but the outermost two planets in our Solar System. We have seen, on our TV screens and printed in books and magazines, the Moon-like craters of Mercury, the lava fields of Venus, the red rocks and dunes of Mars, the planet-size hurricanes in Jupiter's atmosphere, the millions of rings round Saturn, giant ravines on the moons of Uranus. ... Just as in the 19th century, when photography looked set to make artists redundant, one may ask whether space artists are now really needed?



Mount Pico, which rises 2,400 m from the lunar Mare Imbrium, as modelled by Nasmyth and Carpenter in *The Moon* (1874).

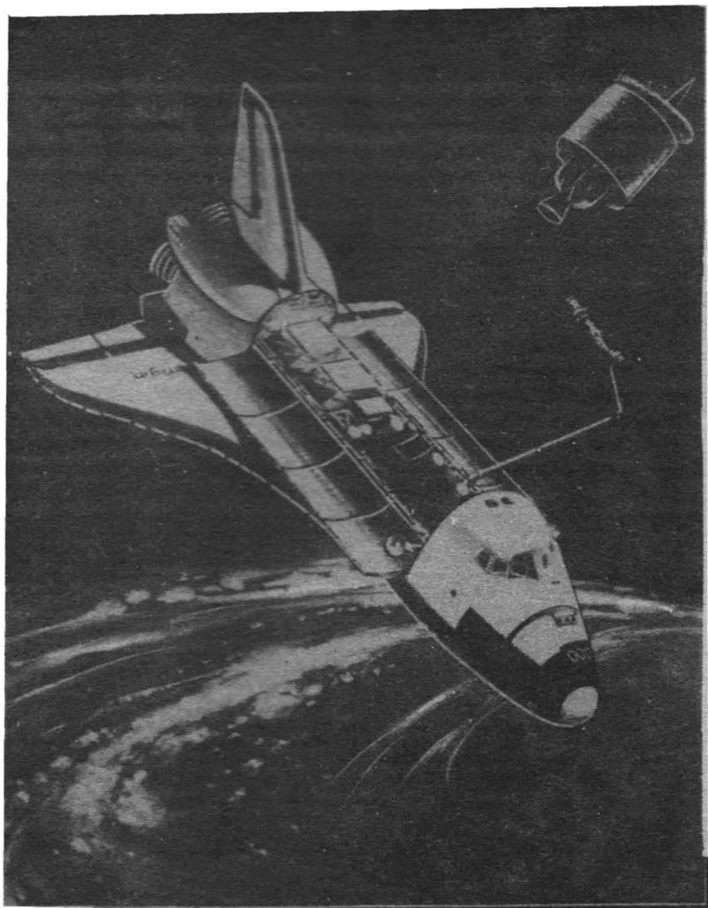
The initial answer to this is obvious: so far we have only explored our own planetary system – and that mostly by robot. Artists are still able to portray the planets of other stars, distant galaxies, black holes and so forth much more graphically than any photographic plate or video image. Future space projects, such as Hotol or bases on the Moon or Mars, also require artistic interpretation to give them an element of reality. But even supposing that we limit our canvas to our own Solar System and what has already been accomplished, then the artist still has his uses.

As I said, most of our neighbouring bodies have been viewed only by automated probes. Actual photographs taken by Apollo and Shuttle astronauts show how much can be added by the hand of Man. (And no artist has yet gone into space.) Further, with the exception of Venus and Mars, the pictures we have received were taken from a distance of some hundreds or thousands of kilometres away from the body, looking vertically down or from an oblique angle. Only the artist can 'correct' or interpret these views to show the landscape as it would be – and one day will be – viewed from the surface.

The images we are used to seeing are really more in the nature of interpretations of data. There is controversy, for instance, over whether Io is really red and orange, like a giant pizza, or is actually a pale lemon-green. The cloud belts of Jupiter and Saturn are not really as garish as we are often led to believe, because the results have been computer-enhanced. A reputable artist's impression, based on these, is likely to be closer to the truth.

Recording Historic Events

So today we have paintings of most of the planets

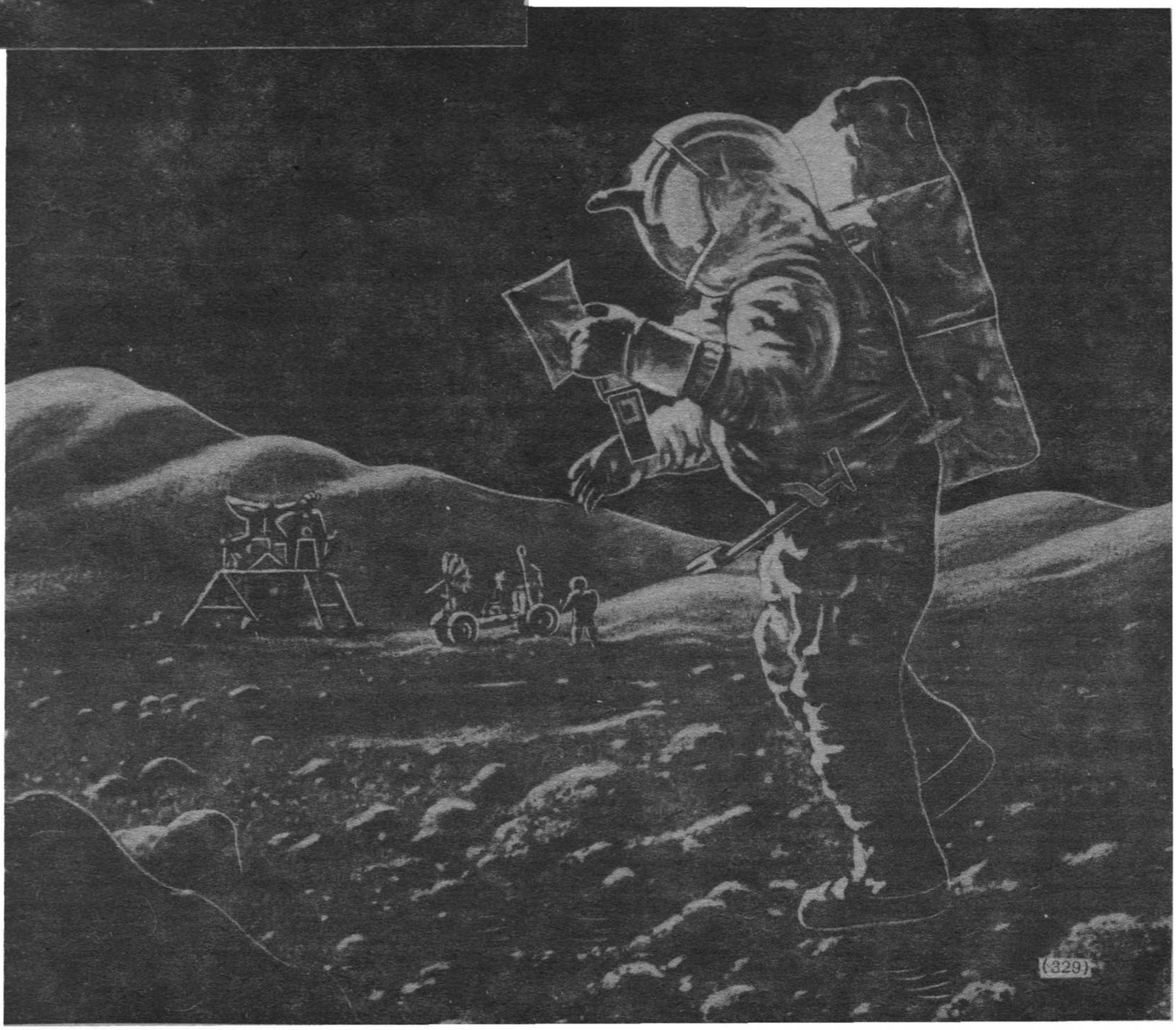


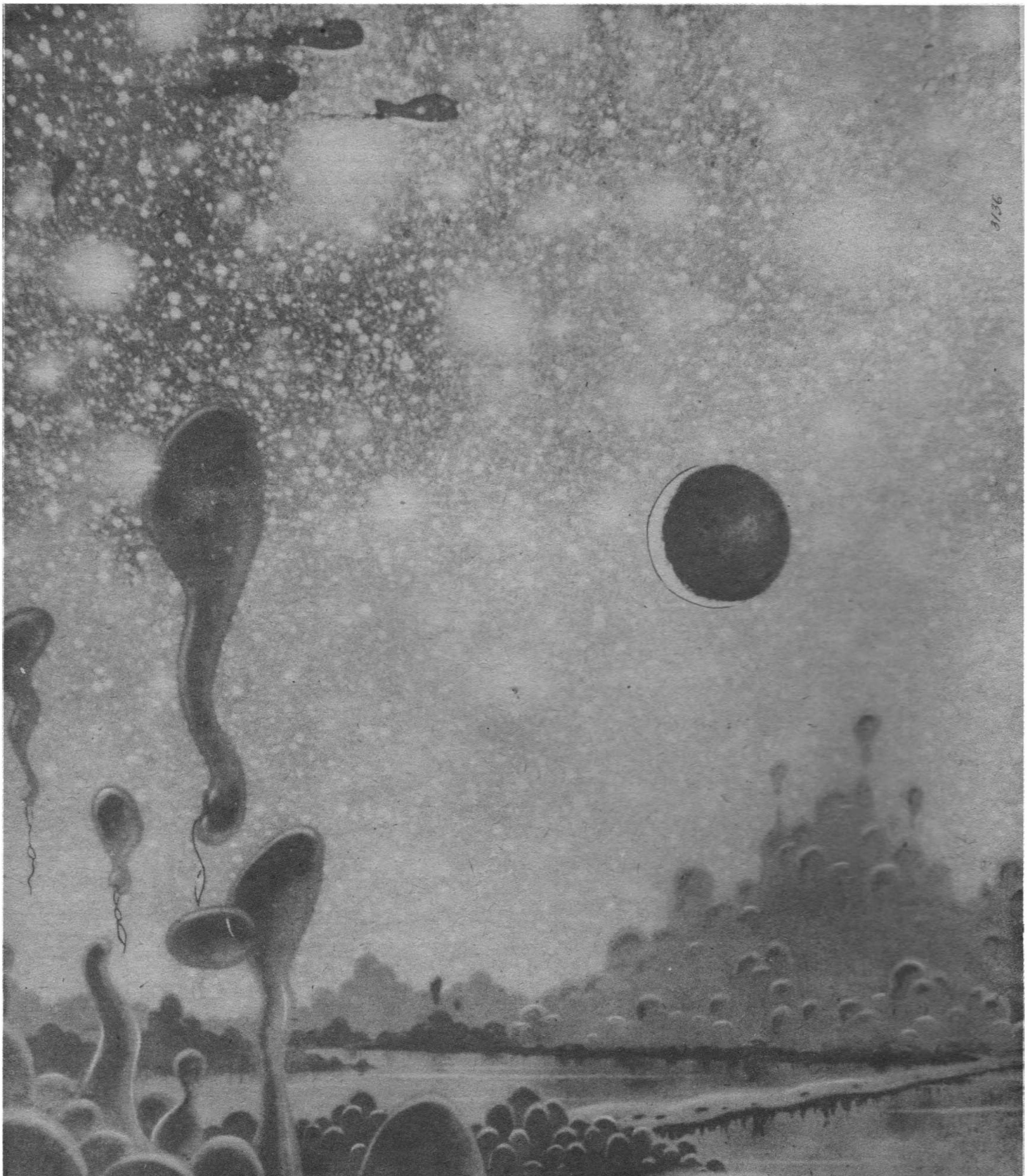
and satellites which are as close to photographs as one could wish, tempered only by the individual style of the artist (which can be eliminated completely, if he or she wishes. The use of the airbrush is a great aid to this.) But there is another important aspect of the space artist's task. We have had photographs from space ever since the Mercury and Gemini programmes, usually taken by the astronauts' hand-held cameras. But there is no still photo of the first man on the Moon. Neil Armstrong had the only camera, so the only glimpse we get of him is reflected in Aldrin's gold-plated face-plate. What an omission, for NASA not to have included a camera with an auto-timer!

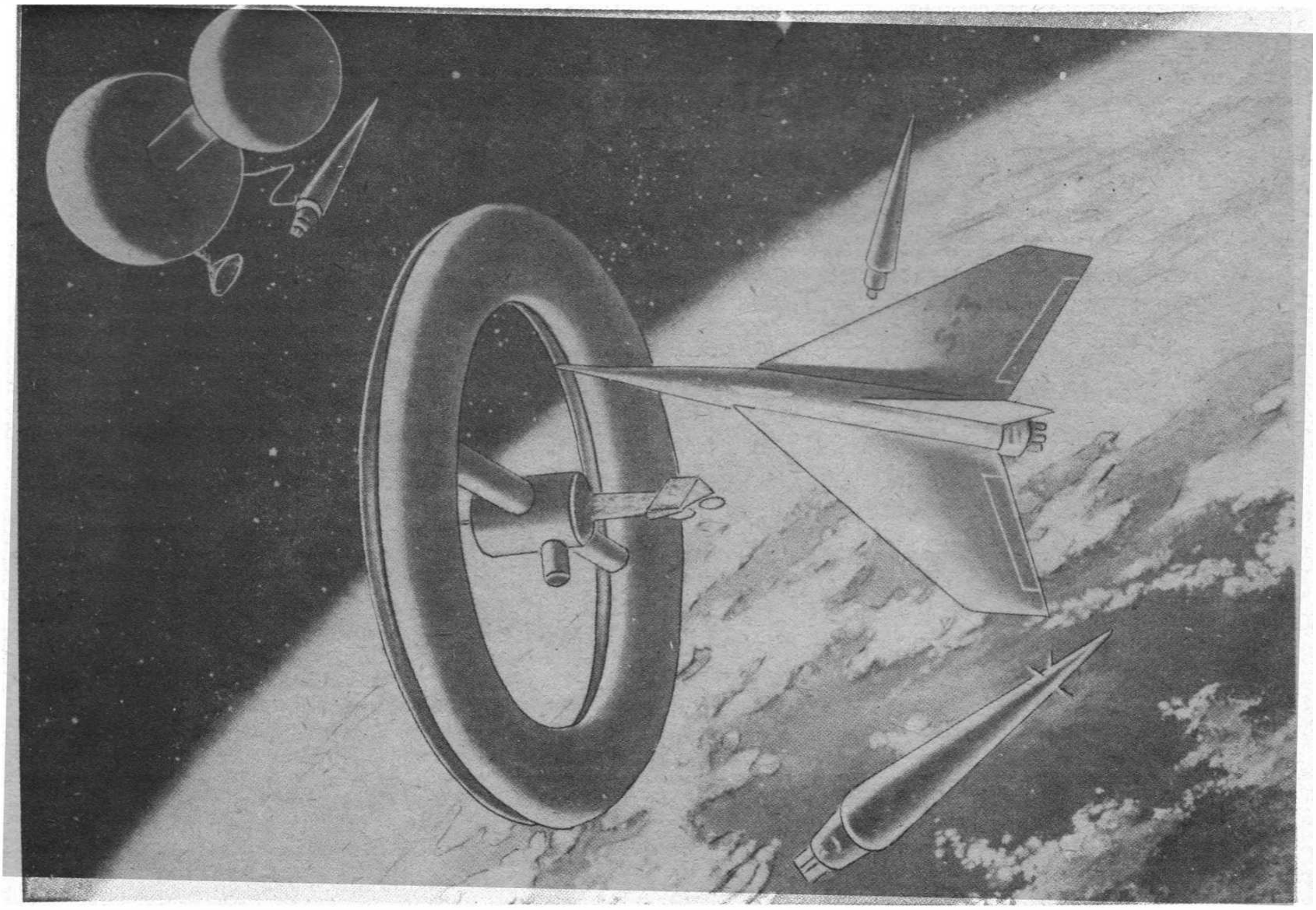
And what of historic events such as dockings in space? Oh, we have pictures of one craft taken from another – but where is one of, say, Skylab with the Apollo CSM in its docking port? In theory, it would have been possible for an astronaut to 'spacewalk' to a suitable distance to snap docked craft, but until the Shuttle there are no pictures taken by a free-floating crew member (and even here the angles are somewhat limited). Where are the photographs of Viking landing

Shuttle astronauts are usually too busy when launching satellites to take a camera on EVA to record the process. (© *David A. Hardy, from the private collection of P.Joannou*).

Although the Apollo astronauts took photographs of each other, the picture below would be impossible without an auto-timer – or a third party. (© *David A. Hardy, from the private collection of P. Joannou*).







Early influences. In 1954, David Hardy painted this Space Operations Centre, drawing upon von Braun's 'wheel' space station, Arthur C. Clarke's 'dumb-bell' nuclear-powered deep space craft, and his adaptation of R. A. Smith's ferry rockets and tankers. At this time, the only photos of Earth were a few soot-and-whitewash views from V-2s and Vikings.

on Mars, or of Voyager as it flies by Jupiter, Saturn or Uranus? These are left for the artist to create.

In his 1953 short story 'Jupiter Five' Arthur Clarke described a mission by a journalist, to photograph scenes on the moons of Jupiter and Saturn which duplicated as closely as possible Bonestell's paintings reproduced in *Life* magazine in 1944. Prophetic though many of Arthur's ideas have been, this is not likely to happen in fact, because those satellites have proved to have much greater variety, to be more interesting and even more active, than could have been envisaged from the observations of tiny spots of light, measurements of albedos, and spectroscopic readings possible in those days. This is not to decry the value of those early illustrations, which in their day made other worlds more real than any telescopic photograph or mere description could do.

In the picture on the left ***David A. Hardy*** *presents the prospect of life existing in a distant part of the Universe. The scene is on a planet in a globular cluster where an alien form of life has evolved. A globular cluster is a compact system of over half a million stars at least as luminous as the Sun with very many dimmer stars. The planet's 'night' sky would be spectacularly bright due to the density of neighbouring stars some of which would appear as bright as our full Moon while the background sky would glow by the light of myriads of remoter stars. The artist postulates massive colonies of oxygen-filled bladders, anchored to land or forming great rafts on an ocean, maturing and finally floating free into a carbon dioxide atmosphere, where they rise and travel on the wind. Such a scene is of course pure speculation, but one that prompts the question 'Can life take such totally alien forms, or will it, if encountered, be basically Earth-like? In the picture we also see a moon of our hypothetical planet.*

© David A. Hardy

The history of astronomical art is full of instances of 'how we got it wrong'. Witness the Carboniferous jungles of Venus, the canals of Mars, with its blue sky (now pink), the blue sky of Titan (now red smog). It's all part of the fun. Artists can only get it as right as scientists allow. Once, Mercury had a twilight zone dividing a side of eternal day and one of eternal night. Once, Jupiter had 11 moons, Saturn had three (perhaps four) rings and nine moons, and Pluto had no moon at all. But as long as astronomers continue to find 'new' objects in space, as they found pulsars, neutron stars and quasars; or to come up with new theories on the origins or end of the universe, space artists – and there are now literally dozens, especially in the USA – will be waiting avidly to portray them.

Space Art Exhibition Success

An International Exhibition of Space Art held during May and June at Utrecht, The Netherlands brought together the work of artists from both East and West. The exhibition was held in conjunction with a major space flight exposition that attracted a paying attendance of 170,000 during the nearly two-month period. The 126 exhibits of space art covered astronomical, 'hardware', impressionistic, surrealistic and satirical subject matter.

The United States was represented by paintings by Alan Bean, Chesley Bonestell, Don Davis, William K. Hartmann, Pamela Lee, Robert T. McCall, Ron Miller, Pierre Mion, Rick Sternbach, and an acrylic sculpture by Richard Murray. The Union of Artists of the USSR sent 75 paintings and graphics. Works included paintings by Andrei Sokolov, Yuri Pokhodaev, and Cosmonauts Alexei Leonov and Vladimir Dzjhanibekov. European artists were represented by Ludek Pesek (Switzerland), Lilika Papanicolaou (Greece), David A. Hardy (United Kingdom), Walter Bulander (West Germany), and a number of Dutch artists, including Hans Martens.

An Invitation to:

SPACE '86

to be held on the weekend

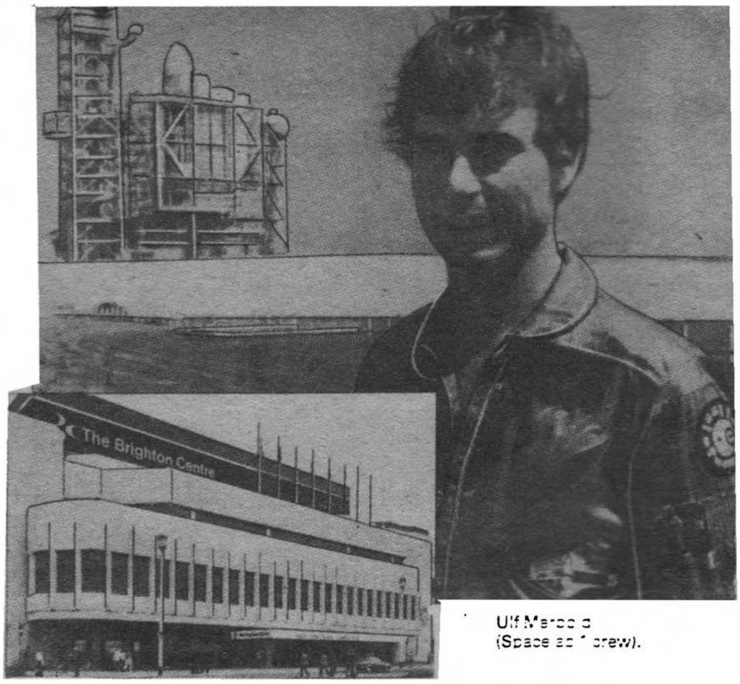
26-28 September 1986

at

THE BRIGHTON CENTRE

on the theme

SPACE: PROFILES OF THE FUTURE



Ulf Merbold (Spacelab 1 crew).

Registration on arrival

The Registration Desk in the Brighton Centre will be open as follows:

Friday (26 September): 2-5 pm.

Saturday and Sunday (27-28 September): am and pm.

Participants without prior postal registration can obtain tickets for the Civic Reception at 8 p.m. (with supper at 9.30 p.m.) on Friday (26 September) from the Registration Desk between 2 and 5 pm on that day.

Postal Registration

Please complete and return the form below with remittance enclosed as soon as possible. Confirmation of registration will be sent to you by return of post. Please report to the Registration Desk to confirm your arrival and to collect Banquet tickets ordered.

Programme

SPACE '86 will take participants 'behind the headlines' to meet and hear first-hand from those who sit in the 'action seats' and are among the leading Space Experts in the UK, Europe and the USA. Speakers include Dr Reimar Lust, Director-General of the European Space Agency; Roy Gibson, Director-General of the British National Space Centre; Jesse Moore, Director of NASA's Johnson Space Center; Prof Graham Smith, Astronomer Royal; Prof J.L. Culhane, Director of the Mullard Space Science Laboratory; Dr R.C. Parkinson, British Aerospace; Dr D.J. Shapland, of the ESA Astronaut Office and many others representing a galaxy of space expertise.

We will hear about Hotol, the Space Station, the Columbus Space Programme, Earth Observation, Microgravity, Robotics, Computing and the role of men in space.

Meet the Astronauts

Astronauts Claude Nicollier (ESA scientist-astronaut) and Ulf Merbold (Spacelab 1 crew) will participate in a Question-and-Answer session.

Social Events

Participants are invited (together with accompanying spouse or near relative) to attend an Opening Reception given by Brighton Corporation on the Friday evening and a Banquet arranged by the BIS on the Saturday evening. Accompanying persons are at liberty to attend any of the Conference sessions if they so wish and they will also have the opportunity of joining a private one and a half hour tour of the Brighton Pavilion, with coffee provided.

Hotel Accommodation

Ample accommodation is available among Brighton's 160 hotels and guest houses. All major hotels are situated within about three minutes walk of the Brighton Centre. A FREE accommodation-finding and reservation service is provided by Brighton Resort Services Department.

Registration Fees	Full Session	
Non-Members	£40	($60)
Society Members	£35	($52)
Members under the age of 21	£15	($22)
Accompanying Person	£6	($9)
4-course Banquet Ticket (including wines)	£20	($30)
Opening Cocktail Reception	Free	
Tour of Royal Pavilion	1.50	($3)

REGISTRATION FORM for SPACE '86, September 26-28, 1986

Please send to: Space '86, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, England.

NAME ....

(ACCOMPANIED BY: ....)

ADDRESS: ....

....

AFFILIATION AND POSITION: ....

.... TEL: .... EXTN: ....

Please register me/us for Space '86. I enclose:

REGISTRATION FEE AND OPENING RECEPTION FEE £

BANQUET TICKETS £

TOUR OF ROYAL PAVILION £

The above covers Registration, Opening Reception, mid-morning and mid-afternoon refreshments and complimentary material distributed at the meeting.

SPECIAL NOTES

1. A full programme will be issued to every participant in due course. Although every attempt will be made to adhere to the published programme, the Society cannot be held responsible for changes due to reasons outside its control
2. The full fee is payable in advance and includes attendance at all sessions during the conference including Opening Cocktail Reception, coffee and tea breaks and complimentary materials. The fee does not include hotel accommodation. Registration Fees are non-refundable.
3. Hotel accommodation can be handled by Brighton Resort Services Department. A wide range of accommodation is available. Those who wish to make use of this service please tick here ☐

Please photocopy this form

EUROPEAN RENDEZVOUS

ESCAPE SYSTEM FOR HERMES MINI SHUTTLE

A solid rocket motor system that would enable the proposed Hermes mini-shuttle to separate from the Ariane 5 booster in case of emergency during launch has been added to initial design plans.

Four solid propellant boosters would separate Hermes from the Ariane booster and then orbital engines, a second of which has also been added, would power the craft to a runway landing.

Hermes is designed for cargo and crew supply missions to space stations, orbital repair of satellites and platforms, and space observation or science missions.

The French-inspired programme was recently brought within the ESA (European Space Agency) framework and technical studies designed to assess in more depth the project's feasibility are due to start this autumn as the first stage of Hermes being incorporated into the future ESA programme.

The studies, known as the Preparatory Programme, are expected to conclude in the early part of next summer and will make available the necessary information to complete the programme from the technical viewpoint, in terms of coherence with other elements of the basic European infrastructure (Columbus, Ariane 5 and the Delta Relay Satellite) and with regard to cost, timetable and industrial structure.

The Preparatory Programme will include a series of industrial activities aimed at the detailed definition of the mini-shuttle, together with studies on specific uses of Hermes and a definition of its role in extra-vehicular activity.

This initial phase will prepare the way for ESA member states to take a final decision in mid-1987 on Hermes. If the project goes ahead on this time-scale the first launch could take place around 1995.

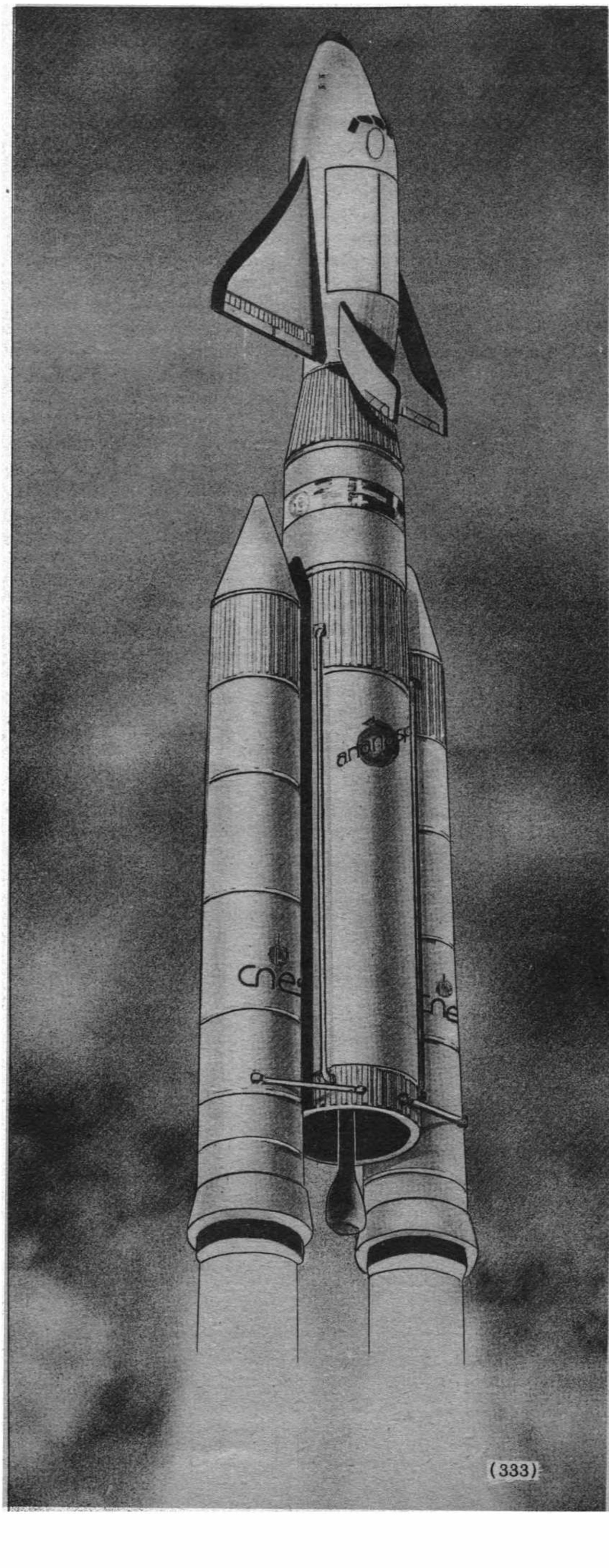
GERMAN HOTOL COMPETITOR

West Germany is developing its own idea for a spaceplane as a possible ESA project that would become operational in the early part of the next century.

The 'Sanger' spaceplane would be seen as a successor to the US Shuttle and the French plans for a mini-shuttle, but a rival to the UK Hotol plans.

It would use an air-breathing first stage aircraft which would carry the orbital vehicle to an altitude of 18 miles. The orbiter would then separate and be propelled to an orbital altitude of 250 miles by a conventional rocket engine.

Like Hotol it would be able to take-off and land on conventional runways and be capable of carrying passengers and cargo into low Earth orbit for around one fifth of the cost of Hermes or the US Shuttle.



An Ariane 5 rocket, the largest member of the European launcher family, boosts the manned Hermes mini-shuttle towards orbit. Both the shuttle and the booster are still in early stages of planning and development *CNES*

EUROPEAN RENDEZVOUS

NEXT ARIANE LAUNCH

Engineers working on the third stage of the Ariane launcher expect to have identified the modifications needed by this autumn in time for a resumption of launches early in 1987.

The third stage cryogenic HM-7 engine failed during mission V18 on May 30 leading to the loss of the rocket and its Intelsat V F14 satellite payload (See ***Spaceflight***, July/August 1986, pp 294).

A board of inquiry reported at the beginning of July that investigations had not revealed any manufacturing faults in items of hardware, the engine or propulsion units.

However, it recommended a complete redefinition of the third stage ignition sequence which was identified as the cause of the accident. The 14 recommendations submitted by the inquiry board covered the following:

- Complementary studies on the ignition conditions.
- Redefinition and qualification of a more powerful third stage ignitor.
- A schedule of firing tests in simulated flight designed to validate the new ignition conditions and the engine for flight V19.
- A review of the third stage (HM-7) acceptance process.

The inquiry board noted that thermal performance of the third stage ignitor was weak and that there was a high probability that operating margins for ignition were surpassed on mission V18.

* * *

The International Maritime Organisation (Inmarsat) has confirmed plans to launch a second Inmarsat-2 communications satellite on the European Ariane 4.

Launch is scheduled for spring 1989 following the first Inmarsat-2 the previous autumn. The spacecraft are being built by an international consortium led by British Aerospace.

ULYSSES GOES INTO STORAGE

The Ulysses spacecraft, an international effort intended to study the poles of the Sun and interstellar space, has been returned to the European Space Agency (ESA) following the decision to terminate development of the Centaur upper stage (see p. 340).

The spacecraft was loaded aboard an Air France Boeing 747 on June 17 and flown to the European Space Research and Technology Centre in Noordwijk, The Netherlands, where it is being stored pending future project activity.

While housed in NASA facilities at the Cape Canaveral Air Force Station, Ulysses underwent a successful testing programme. The spacecraft was due to be mated with its Centaur upper stage and tested as an integrated unit before being loaded into the payload canister for transfer to the launch pad. At the time of the Shuttle 51L accident, Centaurs were in the final months of preparation for the launches of Ulysses and Galileo, then scheduled six days apart in May.

The Ulysses spacecraft, a joint project between NASA and ESA, arrived at Cape Canaveral Air Force Station on January 6, 1986. About 45 team members representing more than 12 different nationalities from ESA and Dornier Systems, builder of the spacecraft, arrived to assist in its pre-launch processing.

FRENCH COSMONAUTS

The French national space agency (CNES) has announced the selection of Jean-Loup Chretien for the joint flight with the Soviets to the Mir space station in 1988. Michel Tognini is the back-up.

SERC INPUT TO SPACE PLAN

The Science and Engineering Research Council (SERC) is to replace its Astronomy, Space and Radio (ASR) Board by a new Board to advise the Council on astronomy and associated research in the Solar System, covering both ground and space-based techniques.

The move is part of SERC's efforts to strengthen its participation in the work of the British National Space Centre (BNSC). At the same time, the Council has formed a Space Planning Committee to recommend an overall space plan bringing together the space interests of the Council's various Boards with maximum contribution to BNSC's space plan.

NASA Sets New Shuttle Target

Expendable US rockets could be in action again this autumn putting the country back in the launch business – but the Space Shuttle will not fly again until 1988 at the earliest.

Shift in the launch target date for the next Shuttle flight from July next year to the first quarter of 1988 was revealed by NASA administrator James Fletcher in his report to President Reagan on how the agency intends to implement the findings of the Challenger Commission inquiry.

The report says that work on a new booster design means that the first flight of the Shuttle following the launch disaster on January 28 "will not occur prior to the first quarter of 1988".

It also gives details of the following action already taken by NASA as a result of the recommendations (***Spaceflight***, July/August, 1986 p.292) in the Presidential Commission Report.

Solid Rocket Motor Design.

On March 24, 1986 the Marshall Space Flight Center (MSFC) was directed to form a Solid Rocket Motor (SRM) joint redesign team which has since evaluated several design alternatives. Analysis and testing are in progress to determine the preferred approaches which minimise hardware redesign. To ensure adequate programme contingency in this effort, the redesign team is also developing a totally new design which does not use existing hardware.

Design verification and certification will include tests which duplicate actual launch loads as closely as feasible.

NASA is currently considering building a facility which would enable the SRB's to be tested in a vertical position. Previously all booster test firings have been carried out on the horizontal.

Launch pad 34 is one of two at Cape Canaveral Air Force Station which is being examined as a possible site of the new testing facility. The other is pad 37B. Both were used in the 1960's for test flights of the Saturn rockets – pad 34 is where the three Apollo astronauts died in the 1967 capsule fire.

Shuttle Management Structure

General Sam Phillips, who served as Apollo programme director, has been appointed to study every aspect of how NASA manages its programme, including relationships between various field centres and NASA headquarters. General Phillips has broad authority from the administrator to explore every aspect of NASA organisation, management and procedures. His activities will include a review of the Space Shuttle management structure.

Astronaut Robert Crippen was directed to form a fact-finding group to assess the Space Shuttle management structure.

Rear Admiral Richard Truly, a former astronaut, has been appointed as associate administrator for the

Vandenberg's Shuttle Future in Doubt

Space Shuttle Columbia is still expected to be delivered to Vandenberg Air Force Base this October for launch pad testing despite a recommendation to mothball the west coast Shuttle launch and recovery facility until the early 1990's.

The US Air Force has made the recommendation on the basis of a reduced orbiter fleet following the Challenger loss and various safety issues still to be resolved at the site which was originally scheduled to have been used for its first Shuttle launch earlier this year.

To date $3.3 billion has been invested in the Vandenberg Shuttle launch and recovery complex and there are currently some 3,300 people working on the site for the four main contractors and the Air Force. Also in storage at Vandenberg are three external tanks and a flight set of filament wound case solid rocket booster segments.

Columbia, originally to have been shipped to Vandenberg in July (*Spaceflight*, June 1986, p. 242) atop the modified Boeing 747 Shuttle Carrier Aircraft, is expected to remain at the Air Force Base for seven months.

The Orbiter Discovery riding piggyback its Boeing 747 transport overflies the Vandenberg Shuttle facility during an earlier stage of construction.

Office of Space Flight. Several active astronauts are currently serving in management positions in the agency.

A Shuttle safety panel was due to be established by the associate administrator for Space Flight in early September.

Critical Item Review and Hazard Analysis

On March 13, 1986 NASA initiated a complete review of all Space Shuttle programme failure modes and effects analyses (FMEAs) and associated critical item lists (CILs).

Each Shuttle project element and associated prime contractor has been conducting separate comprehensive reviews which will culminate in a programme wide review with the Shuttle programme manager at Johnson Space Center before the end of the year. Technical specialists from outside the Space Shuttle programme have been assigned as formal members of each of these review teams.

As recommended by the commission, the National Research Council has agreed to form an Independent Audit Panel, reporting to the NASA administrator, to verify the adequacy of this effort.

The CIL identifies the critical failure modes and the rationale for retention. The items in the CIL are classified in five major categories commensurate with the degree of criticality. The five classifications are:

1 – Loss of life or vehicle.
1R – Failure of both redundant hardware elements could cause loss of life or vehicle.
2 – Loss of mission.
2R – Failure of both redundant hardware elements could cause loss of mission.
3 – All others.

Landing Safety

A Landing Safety Team has been established to review and implement the commission's findings and recommendations on landing safety. All Shuttle hardware and systems are undergoing design reviews to insure compliance with the specifications and safety concerns. The tyres, brakes and nose wheel steering system are included and funding for a new carbon brakes system has been approved.

Runway surface tests and landing aid requirement reviews had been underway for some time prior to the accident and are continuing. Landing aid implementation will be complete by July 1987. The interim brake system will be delivered by August 1987.

Improved methods of local weather forecasting and weather-related support are being developed. Until the Shuttle programme has demonstrated satisfactory safety margins through high fidelity testing and during actual landings at Edwards Air Force Base, the Kennedy Space Center landing site will not be used for nominal end-of-mission landings. Dual Orbiter ferry capability has been an issue for some time and will be thoroughly considered.

Launch Abort and Crew Escape

On April 7, 1986 NASA initiated a Shuttle Crew Egress and Escape Review. The scope of this analysis included egress and escape capabilities from launch through landing and will provide analyses, concepts, feasibility assessments, cost and schedules for pad abort, bailout, ejection systems, water landings, and powered flight separation.

The review specifically assessed options for crew escape during controlled gliding flight and options for extending the intact abort flight envelope to include failure of two or three main engines during the early ascent phase.

In conjunction with this activity, a Launch Abort Reassessment Team was established to review all launch and launch abort rules to ensure that launch commit criteria, flight rules, range safety systems and procedures, landing aids, runway configurations and lengths, performance versus abort exposure, abort and end-of-mission landing weights, runway surfaces, and other landing-related capabilities provide the proper margin of safety to the vehicle and crew.

Crew escape and launch abort studies are due to be complete on October 1, 1986 with an implementation decision in December 1986.

Flight Rate

In March 1986 NASA established a Flight Rate Capability Working Group and two flight rate capability studies are currently underway:

1. A study of capabilities and constraints which govern the Shuttle processing flows at the Kennedy Space Center.
2. A study by the Johnson Space Center to assess the impact of flight specific crew training and software delivery/certification on flight rates.

NASA strongly supports a mixed fleet to satisfy launch requirements and actions to revitalise the US expendable launch vehicle capabilities.

Additionally, a new cargo manifest policy is being formulated by NASA headquarters which will establish manifest ground rules and impose constraints to late changes. Manifest control policy recommendations will be completed in November 1986.

TITAN FLAW UNDETECTED

A procedural error in manufacture rather than a design flaw is now thought the most likely cause of the Titan launch failure on April 18 (***Spaceflight***, June 1986, p.239) which resulted in the loss of a "big bird" military satellite.

The investigation into the accident revealed that insulation protecting the booster's steel walls probably peeled away, exposing them to super-hot gases and flame which quickly ate through the booster.

When the Titan 34D exploded in a huge fireball nine seconds after lift-off it was only 800 feet off the ground. Damage to the launch pad and a nearby pad was estimated at $70m.

Around 95 per cent of the Titan booster was recovered by salvage teams, providing good evidence to the accident investigators of how and where the rupture occurred.

It is believed that the flaw in the insulation and its bonding to the booster casing went undetected in prelaunch inspections and as a result reviews of X-ray and ultrasonic equipment used for inspection have been undertaken.

The Air Force is also conducting an extensive review of the controls used in manufacturing the insulation and it is now estimated that the Titan could be flying again early in the new year.

UP-DATE USA

DELTA SET FOR AUTUMN LAUNCH

The normally reliable Delta rocket could be back in service this autumn if changes recommended by a team investigating the May 3 failure can be implemented as expected.

Delta launches were originally scheduled for mid-August and early October but these are now on hold awaiting completion of the partial re-design of the main engine's electrical system.

The August launch would have deployed a DoD payload, with the October mission carrying a GOES-H weather satellite, the next in the series to the one that was lost in May.

In early July the investigation team reported that the accident was most likely to have occurred when wire insulation in the electrical system of the rocket's main engine was damaged by vibrations in flight.

This damage led to two electrical surges which ultimately caused the rocket's main engine to shut down 71 seconds after lift-off. Twenty seconds later range safety officers destroyed the rocket together with its $57.5m satellite payload.

The investigation also recommended implementing the design changes on the Atlas-Centaur rocket which has a main engine similar to the Delta.

Delta's form the backbone of NASA's launch inventory, ***writes Philip Chien.*** Operational launch pads are maintained on the East coast at Cape Canaveral AFS and on the West coast (for polar orbits) at Vandenberg AFB. Deltas have a 97 per cent success rate, only 11 previous failures out of 177 launches. The last launch failure of a Delta was the September 13, 1977 launch of Delta 134 carrying an ESA communications satellite.

Delta is an outgrowth of the Douglas Thor ICBM, which became operational in 1959, and the first Delta launch was on August 12, 1960 – over a quarter of a century ago. It carried NASA's first communications experiment, the ECHO-1 passive reflector, a 200 pound balloon satellite. The first satellite placed in geostationary "Clarke" orbit, the 146 pound SYNCOM 1, was put aloft by Delta 16 on February 14, 1963.

In its 26 year history the Delta has gone through continuous upgrades and thrust enhancements. The original Thor missile stage was lengthened and upper stages were added. Delta pioneered strapping small solid boosters to the first stage. Present Deltas can place 2,750 lb (1,250 kg) into GTO (Geosynchronous transfer orbit). The Delta 3914 version used on May 3 consisted of a three stage vehicle with nine strap-on boosters.

The first stage uses a Rocketdyne RS-27 main engine, a growth version of the Saturn 1B first stage H-1 engine used for Apollo 7, Skylab, and Apollo-Soyuz flights. It burns a fuel of RP-1, a highly refined aviation grade kerosene, and uses liquid oxygen as an oxidizer. At launch time six of the nine Castor IV motors are fired to provide extra thrust. When they burn out the final three motors are fired. The staggered six-three burn prevents launch pad damage, and reduces strain to the main booster.

Deltas have carried communications satellites, scientific experiments, and weather satellites into orbit. The last successful Delta launch from the Cape was Delta 177, with the Nato III-D communications satellite on November 14, 1984.

ATLAS CENTAUR DELAYED

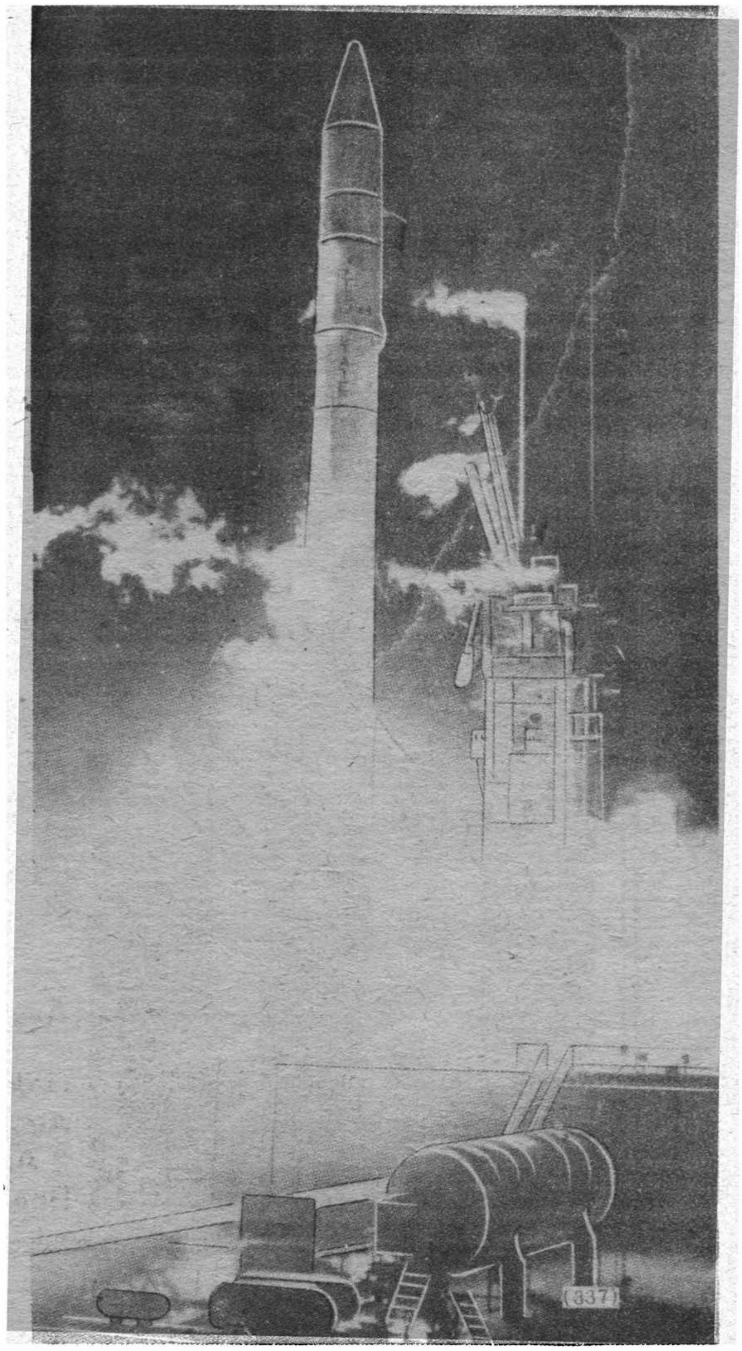
Launch of an unmanned Atlas Centaur rocket carrying a military communications satellite has been rescheduled to early November.

The mission was originally planned for a May 22 lift-off but has been delayed twice following the Delta failure.

A second launch date of August 28 was slipped in mid-July when NASA engineers discovered some of the rocket's electrical components came from lots which experienced high failure rates. Launch is currently scheduled for November 6.

The Atlas-Centaur is the only major US launch vehicle not grounded at present because of the failures in the first half of 1986.

A military communications satellite, similar to that which is due for launch in early November, is put aloft by an Atlas Centaur vehicle in January 1980.



UP-DATE USA

NASA CHANGES IN WAKE OF CHALLENGER

Kennedy Space Center's third director, Richard Smith, surprised his associates July 10 when he announced his retirement after 35 years in Army and NASA positions. He will become president of a new enterprise, General Space Corp., of Pittsburgh, Pennsylvania, owned by Astrotech International. His new firm will endeavour to finance a fourth Shuttle by stock sales if NASA agrees to lease it from the company, *writes* *Gordon L. Harris.*

Smith had directed KSC since August 8, 1979 and concluded his association July 31, 1986. His deputy Thomas Utsman, was appointed acting centre director by the NASA Administrator, James Fletcher, who himself had resigned from the Pittsburgh company's board to rejoin the space agency.

A year before joining KSC, Smith was transferred to Washington in a key position at NASA headquarters related to the space transportation system. He held the KSC job during all 25 Shuttle launches, concluding with the January 28 disaster that destroyed Challenger and its crew.

★ ★ ★

Lawrence Mulloy (52), chief of NASA's solid rocket booster (SRB) programme at the time of the ill-fated Challenger launch, announced his retirement from the agency at the end of July.

★ ★ ★

Dr. William Lucas (64) retired from NASA on July 1. He was director of the Marshall Space Flight Center and his career spanned 34 years of leadership in Army rocketry and NASA space programmes.

For most of the 1960's, while working on the Saturn family rockets, he served in progressively responsible management positions within the Center's Propulsion and Vehicle Engineering Laboratory, becoming laboratory director in 1966.

In these postions, he directed the critical selection of major materials and welding techniques for future launch vehicles. He pioneered work with spray-on foams for cryogenic insulation and high-temperature materials, leading the development of the world's largest propulsion system used in the Saturn V launch vehicle.

Lucas was also involved in the design and development of the world's first space station, Skylab.

In 1969, four years prior to the actual launch of Skylab, Lucas was named by Wernher von Braun to direct a new organisation designed to look to the future. In that key position, then later as deputy director of the Center, and finally from 1974 as Center director, Lucas was instrumental in bringing to Marshall a significant share of the nation's major space programmes.

Under Lucas' direction, Marshall was given responsibility for managing three of the four main Shuttle elements – the main engines on the orbiter, the twin SRB's and the huge External Tank. In addition, the Marshall Center has had responsibility for Spacelab.

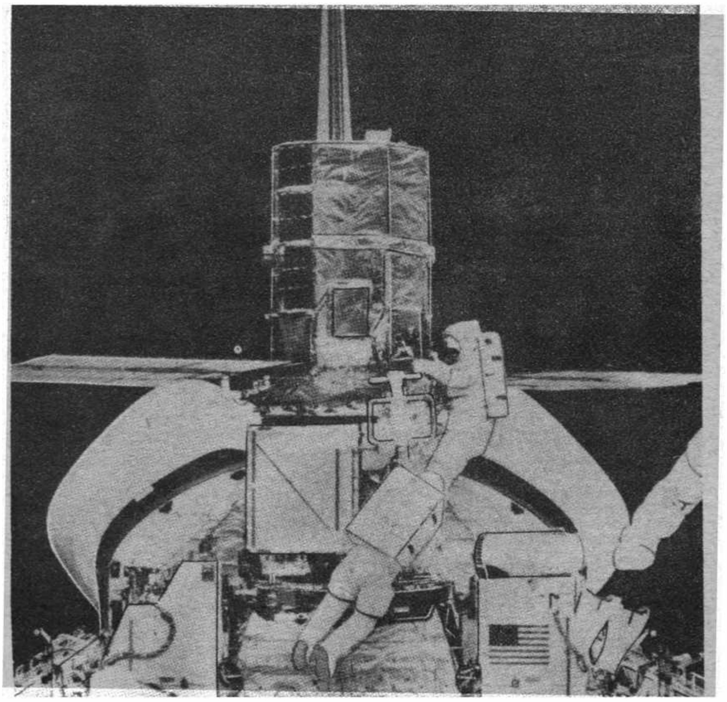
★ ★ ★

Two veteran NASA astronauts each with two space flights to their credit have resigned from the space agency to pursue interests in consulting and private industry.

Owen K. Garriott left NASA during the summer after more than 20 years at the Johnson Space Center and James van Hoften has also resigned.

Highlights of Garriot's career included a two month stay on Skylab and the 10-day Spacelab 1 mission on the Shuttle Columbia in 1983.

Hoften performed extravehicular activities to repair faulty satellites on each of his two Shuttle flights. On mission 41C (April 1984) he and astronaut George Nelson repaired the Solar Maximum Mission satellite and returned it to orbit. In August of last year he performed in-orbit repair of Syncom IV-3 with astronaut William Fisher.



Astronauts James van Hoften and George Nelson repair the Solar Maximum Mission satellite during flight 41C in April 1984.

Notebook From The Cape

by Gordon L. Harris

NASA continues to bleed, albeit the agonising drain has abated somewhat as vested interests run out of arguments supporting their varied causes. One group, within and outside NASA, is pushing for more use of expendable launch vehicles and less dependence upon the shuttles, settling old scores in the process.

Administrator James Fletcher, who once believed shuttles could handle all US space payloads, has come around to supporting a mixed fleet. At the moment, no one seems quite sure what that fleet will consist of – there is much talk of a powerful Titan developed at Air Force expense to accommodate scientific and commercial satellites. Some refurbishment of Complex 41 at Kennedy Space Center is underway. It was installed by the Air Force some years ago on man made islands in the Banana River near NASA Complex 39A.

Titan 34D employs a similar boost system to that of the shuttle in its combination of solid and liquid fueled motors. But it does not compare in lift capability to orbit, or 50,000 pounds to the Moon at escape velocity.

Whether NASA will fall back on Delta or Atlas Centaur for lighter satellites remains to be seen – both belong to an earlier generation of space technology. Production of both ceased several years ago when NASA proudly asserted it could rely exclusively on shuttles. Air Force had left the reservation, so to speak, by persuading Congress to buy the latest Titan version, and 10 were supposed to be in production, before the Challenger disaster.

Jesse W. Moore, former head of the Space Shuttle programme and now head of the Johnson Space Center. He will be one of the speakers at Space '86 (see p. 332).

★ ★ ★

Meanwhile Dr. Fletcher has begun to carry out recommendations of the Presidential Commission by taking into Washington Headquarters a goodly chunck of Space Station management. About 100 jobs will be lost by Johnson Space Center as one consequence. Fletcher said headquarters will be responsible for systems engineering and operational functions, too, under direction of Andrew Stofan, director of Lewis Research Center who becomes an associate administrator. Lewis was one of the field activities that escaped probing during the post Challenger inquiry – that was largely concentrated in the headquarters and manned space centres (Kennedy, Marshall in Alabama and the Johnson centre in Texas).

★ ★ ★

Not the least important effect of the Challenger probe is the emergence of astronauts as critics of who will play vital roles in the "new" NASA.

The disaster gave them reason to speak out publicly about issues they raised without effect in-house. The Rogers Commission and Congressional committees have given them sounding boards and NASA will heed their statements.

Lacking a firm schedule which will not include shuttles in any event, KSC talks of launching three expendable vehicles in the next six months, perhaps a Delta and two Atlas Centaurs. Some 14,000 remain on the payrolls of the launch base - NASA spokesmen say they are engaged in training, paper work, and routine maintenance. Few of them would be directly involved in tentative launches, which would occur on Cape Canaveral Air Force Station and not at KSC proper.

NASA Considers Centaur Replacement

Planetary missions affected by the cancellation of the Shuttle/Centaur upper stage could be switched to expendable rockets or remain on the Shuttle for launch by a new boost motor.

NASA is now considering the two basic choices following the decision by its administrator James Fletcher in mid-July to terminate the programme because of safety concerns.

At the time of the Challenger 51L accident the Centaur stage was in the final months of preparation for the then-scheduled 1986 launches of the Galileo and Ulysses spacecraft for missions to Jupiter and the polar regions of the Sun.

Major safety reviews of the system were already underway at that time and these were intensified to determine if the programme should be continued. The final decision was made on the basis that even following certain modifications identified by the on-going reviews the resultant stage would not meet safety criteria applied to other cargo elements of the Shuttle system.

Cancellation of the Centaur upper stage combined with the grounding of the Space Shuttle means that the Galileo mission's arrival at Jupiter will be delayed a minimum of six years.

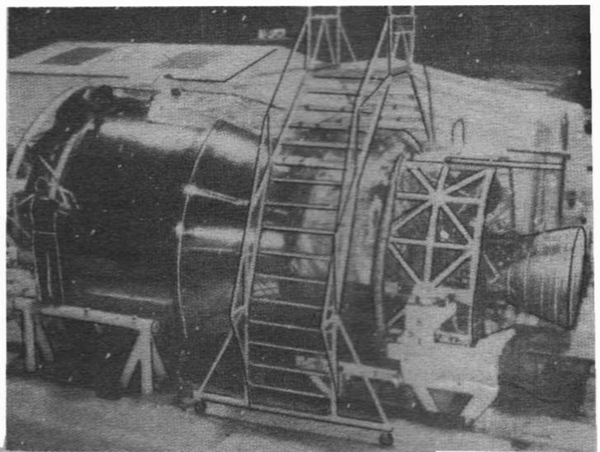
Launch by a new Shuttle stage could occur at the earliest in 1989 but even this date is likely to slip into the early 1990's if it is decided to transfer to an expendable launcher.

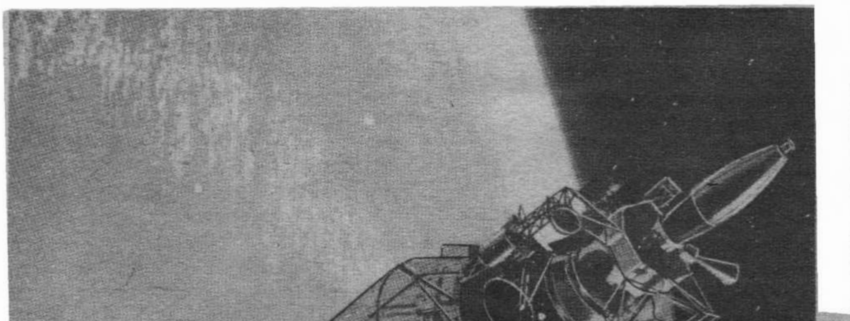
The alternative under consideration for the launch of planetary and scientific payloads by expendables is Titan 34D7. However, this is still under development by Martin Marietta and would probably not be available for use by NASA until 1991. Its first flight is currently scheduled to be with an Air Force payload in February 1990.

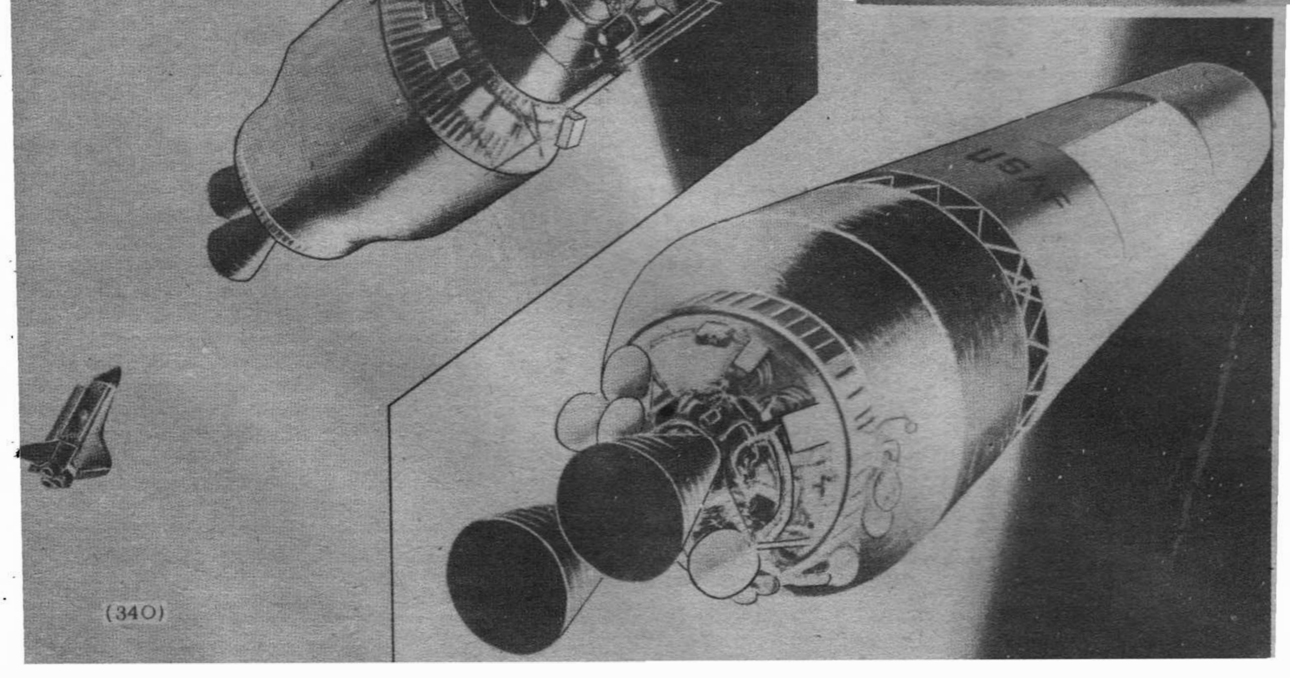
The other option, a new upper stage for use with the Shuttle, would involve developing a new version of an existing solid rocket motor upper stage. Candidates for this include the Boeing Inertial Upper Stage and the Orbital Sciences Corporation Transfer Orbit Stage.

NASA, together with the US Air Force, has spent \$472.8m on development of the Centaur upper stage. Three sets of flight hardware cost NASA a further \$411m. It is estimated that termination of the contract will add another \$60 to \$75m, depending on what happens to the hardware already fabricated.

Galileo and its Centaur G-prime booster (below left), the shorter bodied military version (below right) and a view of a booster stage in preparation. Cancellation of the system means writing off over \$900m.







Solar System Exploration – Mission Status

The Challenger accident on January 28 converted a planned year of intense space activity for NASA into a period of replanning with, of course, the exception of Voyager's spectacular encounter with Uranus on January 24.

For 1986 alone, the Galileo mission to Jupiter, Ulysses to the Sun, and the Hubble Space Telescope were postponed due to the grounding of the three remaining Shuttle Orbiters, pending a resolution of safety questions. A firm date for return of the Shuttles to operational status does not now exist, but estimates place this event sometime in the first half of 1988.

Initial speculation of rescheduling launch dates focused on estimating the date at which the Shuttles might return to service, plus considerations of relative priority in the inevitable backlog of scientific, military, and commercial missions. For interplanetary missions an additional complication arises because launches can only take place when the Earth and the relevant planets are properly aligned. Taking all these factors into account, first guesses at new launch dates moved Galileo and Ulysses from May 1986 to June 1987, but the Magellan mission to Venus held fast at its April 1988 launch date. The Galileo and Ulysses launch slips for direct flights to Jupiter were 13 months because the necessary realignment of Earth and Jupiter takes that long (Ulysses uses Jupiter for gravity-assist purposes in its flight out of the ecliptic and over the solar poles).

The next stage in replanning the launch schedule for the Laboratory's interplanetary missions came with the realisation that safety fixes to the Shuttle and the upper-stage Centaur rocket it would carry were likely to affect the amount of payload the system could inject into interplanetary space. In addition the prospect of getting Galileo and Ulysses launched so close to one another in time did not seem as promising as it had before the accident. Recourse to the bag of celestial-mechanical tricks was indicated in order to find another route to Jupiter for Galileo.

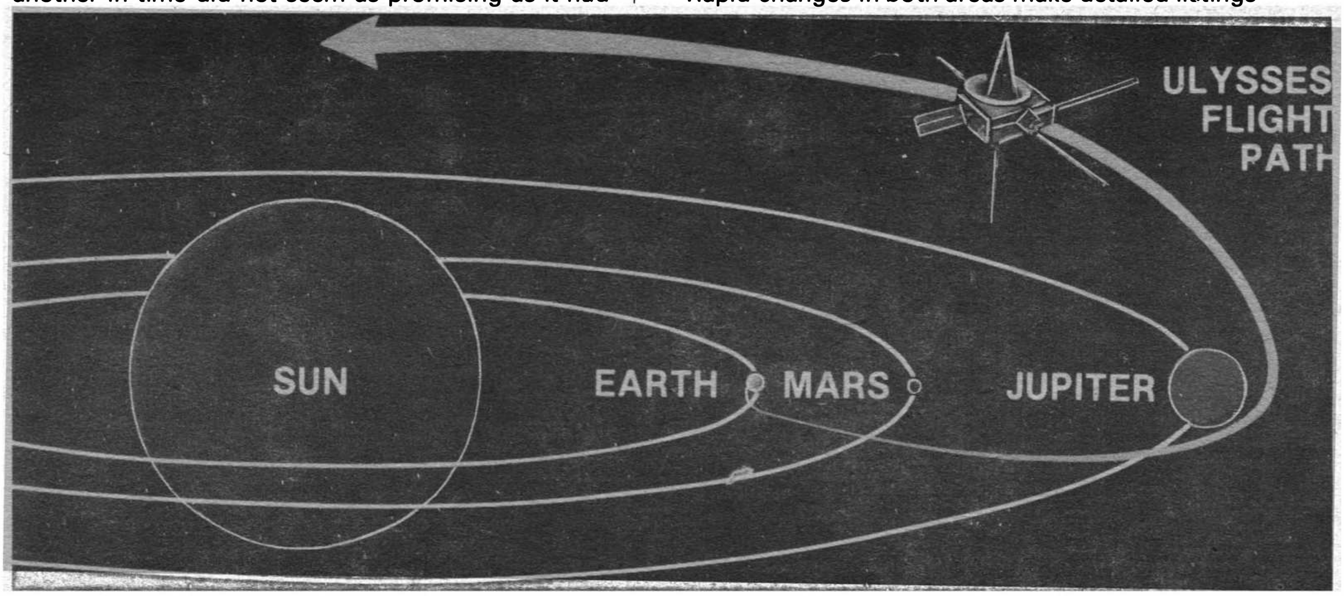
As described in the May issue of this column, a so-called delta-VEGA manoeuvre was proposed; after launch, the spacecraft would perform a loop of almost two years round the Sun, returning to the vicinity of Earth in order to receive a gravitational assist for the flight to Jupiter. This delta-VEGA launch would take place in December 1987, with arrival at Jupiter about four years later. As information continued to become available, the launch date was slipped to December 1988 for Galileo. A delta-VEGA trajectory was still envisaged, but this time the loop would add almost three years to the flight to Jupiter.

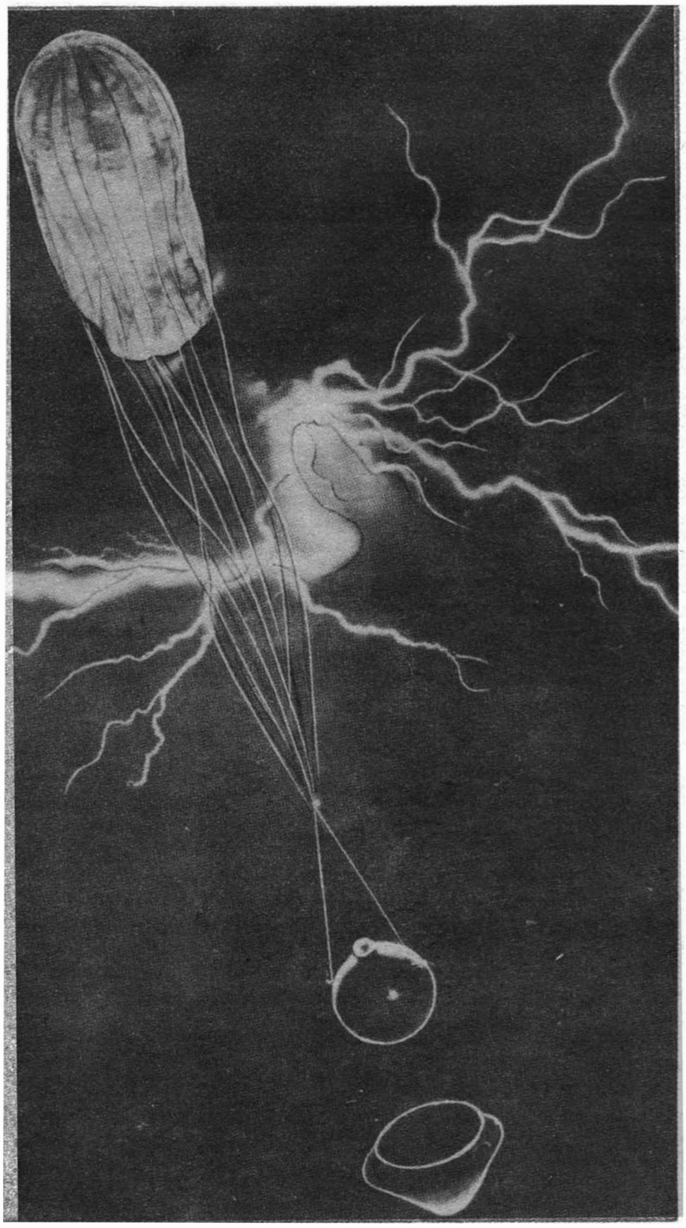
Having shored up this aspect of the programme, attention turned to the state of the Shuttle investigation once again. But ominous rumours began to circulate that the plan to carry the liquid-fueled Centaur inside the Shuttle bay was being questioned on safety grounds, regardless of what safety fixes might be implemented.

On June 19, the blow fell with the confirmation of these rumours – NASA Administrator, Dr. James C. Fletcher, cancelled the Shuttle/Centaur programme for safety reasons. However, the powerful Centaur was not totally gone from the US stable of launchers since the US Air Force continued plans to use it as an upper stage on the Titan expendable launch vehicle.

Progress in getting the planetary flights back on track is now being made through efforts on two fronts. First, numerous alternative launch systems are being analysed, and second, optional trajectories are being synthesized by mission designers with a goal of further reducing energy requirements on launch vehicles.

Rapid changes in both areas make detailed listings





The probe to penetrate the atmosphere of Jupiter which is planned as part of the Galileo mission could now be launched by an expendable Titan booster separately from the spacecraft that will go into orbit around the planet. In this artist's impression the probe's parachute is automatically deployed to slow descent through the atmosphere.

obsolete before they can get into print; so, only generic solutions will be described in the following project summary. Also, in those cases where an expendable launch vehicle is mentioned as a possible alternative, it should be borne in mind that no such vehicles have been allocated to the planetary programme. This is not only a policy question, but, also, expendables will be in short supply in the near future because of military launch needs.

Galileo

The current baseline mission for Galileo envisages a December 1989 or January 1990 launch. This launch would use the Shuttle along with upper stages to be determined. Several solid-rocket combinations are under consideration for the upper stages (as many as three stages might be required), and a liquid upper stage is also possible (but not the Centaur). This strategy would employ a delta-VEGA loop, taking just under two years, and arrival at Jupiter could be as early as September 1994 or as late as November 1995. The long spread in arrival dates is characteristic of this type of trajectory. In addition to providing for upper-stage facilities, it will probably be necessary to expand the size of the propellant tanks on board the Galileo spacecraft in order to perform a large deep-space burn as part of the delta-VEGA strategy.

The time for getting ready for a December 1989 launch is tight. The engineering modifications and tests with regard to the upper stages and expanded tanks must begin soon and proceed expeditiously in order to meet this date. A fall-back option could be to employ a Titan 34D7 with a Centaur G Prime upper stage, but this combination would probably not become available until 1991.

Galileo, with its original May 1986 launch date, was scheduled to arrive at Jupiter in 1988. Several spacecraft systems would need refurbishment in various degrees as the launch dates stretch into the future.

Recent mission studies are focussing on a split mission for Galileo with the Orbiter launched from the Shuttle in late 1989 and the atmospheric probe going on Titan in 1991. Solid upper stages would be employed in both cases.

Ulysses

The baseline mission starts with a September 1989 launch from the Shuttle equipped with upper stages. Ulysses will employ a direct flight to Jupiter since it does not gain from a delta-VEGA manoeuvre.

Magellan

The launch window for the baseline Magellan mission opens in October 1989, using a Shuttle and some upper stage combination. At least three trajectory options have been identified. The first employs a flight path that carries the spacecraft from Earth to Venus in 3¾ months, similar to the plans for the original April 1988 launch. A lower-energy trajectory has been discovered, which requires five months to get to Venus but opens up more options for the choice of an upper stage. A third trajectory option requiring 15 months transit time is also available for a May 1989 launch.

Mars Observer

The August 1990 launch from the Shuttle with a TOS upper stage, built by Orbital Sciences Corporation, has not been affected by the Challenger accident.

Comet Rendezvous/Asteroid Flyby (CRAF)

The proposed CRAF mission, not presently funded, could be flown either with a Shuttle and associated upper stages or a Titan/Centaur G Prime for its planned September 1992 launch.

TOPEX

TOPEX, a cooperative oceanographic mission with France, is designed to be placed in Earth orbit by an Ariane rocket in 1991.

It is disappointing to see the planetary projects delayed for so long, particularly in view of the fact that the last US planetary mission was launched in 1978 (Pioneers 12 and 13 to Venus), and the last JPL-managed planetary mission was launched in 1977 (Voyagers 1 and 2). But, as the above menu shows, the 1990s promise to resume the place of scientific adventure which characterised the 1960s and 1970s and which Voyager has so valiantly maintained in the 1980s.

Voyager Science Summary Published

Following a tradition established by the four Voyager 1 and 2 encounters with Jupiter and Saturn, the early scientific results for Voyager 2's flyby of Uranus have been published in the journal *Science* (July 4 issue).

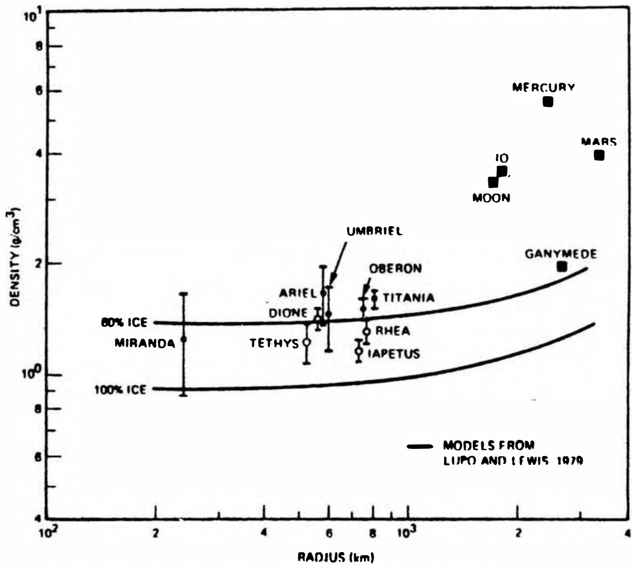
The set of 12 papers is comprised of an overview followed by 11 specialty papers, one for each of the 11 experiment teams: imaging science, photopolarimetry, infrared spectroscopy and radiometry, ultraviolet spectroscopy, radio science (see the June edition of this column), magnetic fields, plasma particles, low-energy charged particles, cosmic-ray particles, planetary radio astronomy, and plasma waves. That modern science is indeed a cooperative venture is seen by the sum of 156 individuals who contributed to this issue; the imaging-science paper topped the list with 40 co-authors.

Since their discovery by Galileo in 1610, the rings of Saturn have furnished one of the glorious sights of the solar system and a rich field for theoretical discoveries. In 1977 rings were discovered about Uranus by means of an Earth-based stellar occultation, and in 1979 Voyager 1 found a ring about Jupiter. Recently, indications of a rather strangely configured set of rings have been found about the planet Neptune.

The nine thin rings of Uranus, discovered before the encounter, were probably the best-known features of the Uranian system, a testimony to the power of the stellar-occultation method. Nevertheless, the passage of the spacecraft produced a wealth of knowledge and several surprises concerning the system of rings. Two new rings were discovered – one very narrow like the other nine and one broad (2500 km) and diffuse. Several partial rings were detected. Probably the biggest surprise arose from the relative scarcity of small-sized ring particles and dust. The typical ring particle seems to be on the order of tens of centimetres to a metre. The explanation of this situation, which differs from that of the Jovian and Saturnian systems, may relate to drag produced by the extended hydrogen atmosphere of Uranus. The drag-induced orbital lifetime of micron-sized particles in the Epsilon ring (the outer ring, which is the largest and brightest) are predicted to be only about 1000 years while centimetre-sized particles would be swept into the planet in only 10 million years, a brief time compared to the age of the Solar System. However, there are smaller-sized particles present in reduced numbers, suggesting a currently active source.

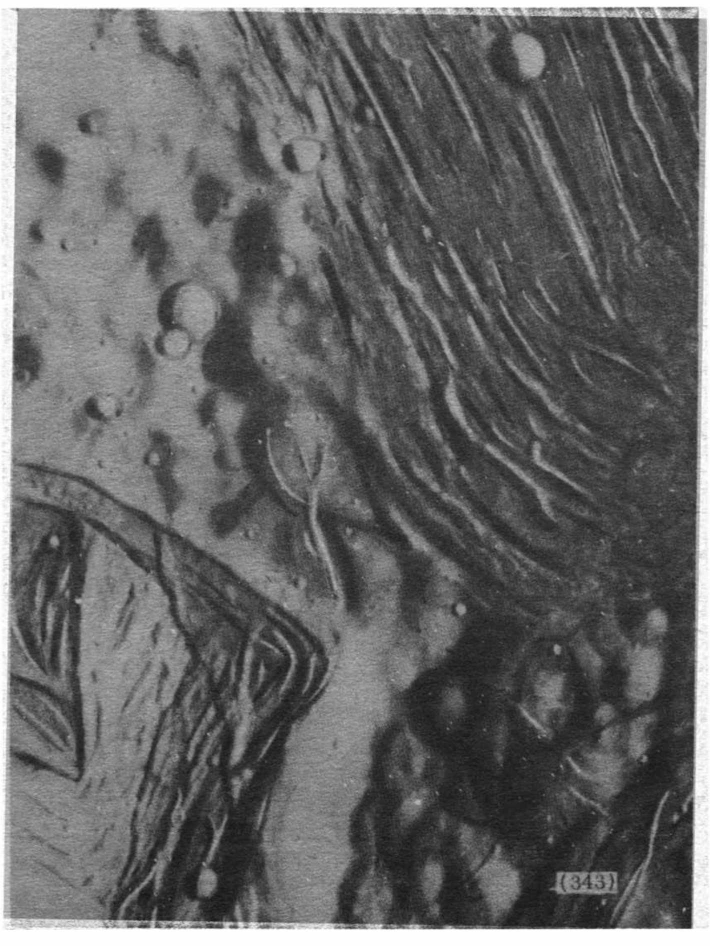
Voyager 2 encountered a 4000 km-thick band of micron-sized particles, registering (without damage) 20 to 30 hits per second as detected by the plasma wave instrument, which corresponds to one particle every 1000 cubic meters. Also, from a vantage point behind the planet, Voyager 2 photographed in one long 96 second exposure a spectacular web of dust structures backlit by the Sun.

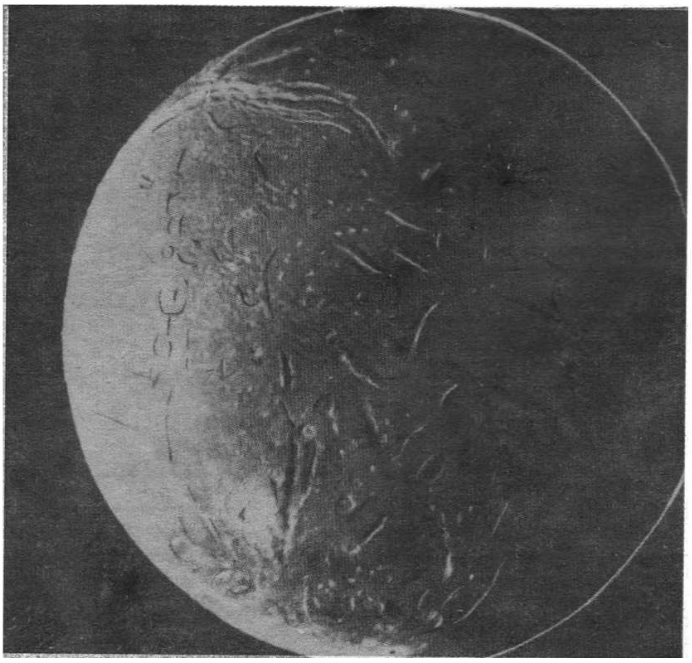
In contrast to pre-encounter knowledge of the rings, very little was known about the satellites except for approximate orbital information and estimates of their diameters based upon their observed brightnesses. The inner of the five previously known satellites, Miranda, showed two quite dissimilar types of terrain: one rolling terrain that is old and heavily cratered and a young complex terrain with parallel sets of bright and dark bands. Ariel showed a young and geologically



The Uranian satellites Miranda, Ariel, Umbriel, Titania, and Oberon are shown in this plot of density versus radius along with other Solar System objects for comparison The vertical bars indicate error bounds on the density estimates The two labelled curves are models for objects consisting of 100 per cent water ice and objects consisting of 60 per cent water ice and 40 per cent silicate, illustrating the effects of self compression

A mosaic of the four highest-resolution images of Ariel represents the most detailed Voyager 2 picture of this satellite of Uranus. The images were taken through the clear filter of Voyager's narrow-angle camera on Jan. 24, 1986, at a distance of about 130,000 km. Ariel is about 1,200 km in diameter; the resolution here is 2.4 km. Much of the surface is densely pitted with craters five to 10 km across. Voyager scientists believe extensive faulting has occurred as a result of expansion and stretching of Ariel's crust The largest fault valleys, near the terminator at right, as well as a smooth region near the centre of this image, have been partly filled with deposits that are younger and less heavily cratered than the pitted terrain. Narrow, somewhat sinuous scarps and valleys have been formed, in turn, in these young deposits. *JPL*





This image of Miranda, obtained by Voyager 2 on approach, shows an unusual 'chevron" figure and regions of distinctly differing terrain on the Uranian moon.

complex surface. Umbriel was much darker than the other large satellites with an ancient topography that has been more recently overlaid by dark material. The origin of the dark material is most likely Umbriel itself – having ejected the material into orbit by an unknown mechanism and then recollected it. Titania and Oberon show similarities on a global scale but differ under higher resolution. The youngest features on Titania are bright-ray craters, perhaps caused by cometary impacts over the last 3000 to 4000 million years. Oberon shows hints of enormous fault structures that could have arisen from a late-stage, global-scale tectonic episode at the end of a complicated geological history.

The origin of the dark material, so prevalent on the satellites and rings, is not known. It could be primordial dark material or it might represent radiation-blackened methane ice.

The mass of Miranda was determined through doppler measurements of its gravitational perturbation of Voyager's trajectory. The masses of the other four large satellites were determined by fitting optical navigation measurements (see the June edition of this column) to numerically integrated models of their motions, the densities in gcm^{-3} are: 1.26 $\pm$ 0.39 (M), 1.65 $\pm$ 0.30 (A), 1.44 $\pm$ 0.28 (U), 1.59 $\pm$ 0.09 (T), 1.50 $\pm$ 0.10 (O), resulting from a mixture of rock and ice. (Water has a density of 1 gcm^{-3}).

Ten new satellites were discovered at Uranus. Most were approximately 50 km in diameter, while one spanned 170 km and showed cratering. As of the date of the publication, the search for new satellites was complete to a diameter of approximately 20 km; subsequent efforts may push this limit down to the 10 km level and, thus, could result in more satellite discoveries.

A trace of methane in the upper atmosphere absorbs in the red, giving the planet its characteristic blue-green appearance. Uranus showed far less visual contrast in its atmosphere than Jupiter or Saturn (largely due to the colder temperatures at Uranian distance), but the overall structure resembles that of the preceding gas giants investigated by Voyager. One fact of note is the comparatively uniform temperature from pole to equator. Because of the peculiar orientation of the spin axis of Uranus, its south pole currently faces the Sun and might be expected to be warmer. But evidently thermal inertia and transport processes have produced a high degree of thermal homogeneity. Measurements showed the atmosphere to be 15 $\pm$ 5 per cent helium (mole fraction) with most of the remainder as hydrogen. At higher altitudes an intense ultraviolet light was emitted almost uniformly from the hemisphere illuminated by the Sun. Christened "electroglow" by the Voyager ultraviolet spectroscopy team, the mechanism is unexplained, but the phenomenon was observed at Jupiter and Saturn as a smaller component of their ultraviolet emissions and seems to be stimulated by sunlight.

The *in situ* measurements of the fields and particles which make up the magnetosphere represent some of the most detailed, intricate, and unique results of the encounter, and the relevant papers should be consulted to gain an appreciation of how much was learned in just a few hours. One of the most celebrated discoveries was the 60 degree angle between the magnetic and rotational poles of the planet and the offset of the magnetic dipole from the planet's centre, yielding a magnetic structure which wobbles its way through space every 17¼ hours as the planet rotates on its axis. The intensity of the field, its inclination, and its offset indicate that it may originate in an ocean where water is under sufficient pressure to be electrically conductive.

The rotation rate of the cloud-covered planet was deduced by monitoring radio emissions from deep below the surface, using the Planetary Radio Astronomy instrument. The rate was independently determined by observing the rotation of the magnetic field.

Energetic protons and electrons trapped in the magnetosphere were measured in significant fluxes. The magnetosphere, unknown before the encounter, was described by the investigators as "moderate sized" and exhibited a complex structure with interaction with the system of satellites.

The encounter of Voyager at Uranus showed science at its best, and we eagerly await the harvest at Neptune in 1989.

New Structure for MIR

The first manned mission to MIR of 125 days duration was successfully completed on July 16 when cosmonauts Leonid Kizim and Vladimir Solovyov returned to Earth.

The holder of the record for the longest time spent in space is now Kizim with 373 days to his credit. Details of the first weeks of the mission were presented in the July/August issue of ***Spaceflight*** by *Neville Kidger*, who now continues with his report on subsequent events involving both the MIR and Salyut 7 space stations.

Ahead of the expected long-term (and possible permanent) occupation of MIR, attention is being focussed on a build-up of orbital hardware to expand the basic capabilities of the space station. Already identified is a large extension module of circular cross-section on which exterior experimental packages can be mounted. The module has its own docking port and would be attached in tandem with the present MIR as shown in the diagram on p. 347.

The build-up of orbital hardware will be greatly accelerated when the Soviet HLLV (Heavy-Lift Launch Vehicle), which is passing through its final stages of development, comes into operation with a 100T payload capacity to low-Earth orbit (LEO).

The events of the last few months have demonstrated a considerable Soviet capability for in-orbit operations and experimentation in the microgravity environment. These activities represent only a pilot-scale operation prior to the introduction of the HLLV, which will be a key element in the subsequent phase of operations in more than one respect. The HLLV is, for example, expected to be mated to a Soviet space shuttle, now under development, and transport it to orbit in order to sustain the number of manned operations required. With future plans well advanced, the first test launch of the HLLV is currently awaited with considerable interest and will be an important landmark in Soviet space development.

Neville Kidger writes:

At 0812 on May 21, the Soviets launched a new "modernised" version of the Soyuz spacecraft. Soyuz TM was launched from Baikonur and entered an initial orbit of 240 x 200 km; period 88.6 minutes, inclination 51.6 degrees. TASS reported that the new Soyuz would conduct joint tests with Mir and said that the new series of Soyuz craft are intended for "delivering crews to multi-purpose manned complexes of the modular type". Soyuz TM docked with Mir's front unit at 1012 on May 23.

Speaking after the docking, Valeri Ryumin told TASS that the new spacecraft was "designed on the basis of Soyuz T" and had the same overall dimensions and crew of three as that craft. The major advance featured by Soyuz TM rested with its docking system, Ryumin said. He explained that when Mir is fitted out with side scientific modules the assembly will prove to be asymmetrical. Therefore, the Igla (needle) approach system, which required both the station and Soyuz to line up for docking, would be of no practical

Cosmonauts Leonid Kizim (right) and Vladimir Solovyov successfully completed a 125-day-long space flight landing on July 16. The "Soyuz T-15" spacecraft landed north-east of the town of Arkalyk. *Novosti*

use. The new Soyuz TM carries an approach system called Kurs (Course) which allows the Soyuz craft to fly an approach to the station's docking ports irrespective of the attitude of the station. Mir uses no fuel during this type of approach.

Soyuz TM also features:

- A new "more reliable" propulsion unit.
- A new communications system, called "Rassvet", which allows Soyuz TM to communicate with FCC via Mir using the Luch geostationary network.
- A new parachute system using stronger and lighter materials than earlier versions.

Improvements to the parachute system in particular mean that more weight is available for payloads both up and down from orbit. The Soviets say that Soyuz TM can carry some 200 kg extra up into orbit and bring back almost 150 kg, an increase of 100 kg, Ryumin also made reference to a new "accident rescue propulsion system" on Soyuz TM.

At 0923 on May 29, Soyuz TM was commanded to undock from Mir. TASS said that the six-day flight had seen tests of the onboard systems and assemblies and structural elements of the modernised spacecraft as well as an orbital manoeuvre with TM's ODU. TASS said that the parameters of the Mir/Progress 26 complex were: height 353 x 335 km; period 91.2 minutes; inclination 51.6 degrees. The Soyuz TM was scheduled to land on May 30, the Soviets said.

At the preset time (not given by the Soviets but around 0520 GMT, according to a western estimate) Soyuz TM landed at an unspecified location.

Salyut 7 - EVA's and the Retractable Girder

Interspersed with the final days of the flight of Soyuz TM, the two cosmonauts on Salyut performed two EVAs of great importance for the future of the Soviet space programme.

During the early part of their stay in Salyut 7 the men had prepared scientific equipment and observed regions of the Earth and oceans. On May 27 the Soviets said that the cosmonauts were in good health but gave no notice that the next day the men were to participate in an EVA. That was normal, what was unusual was that the next day the Soviets broadcast portions of that EVA live on state TV.

The broadcast began at 0725 on May 28 although the EVA itself had begun at 0543. Within 15 minutes of its start, according to the TV announcer and veteran cosmonaut Viktor Savinykh, the two men had retrieved sets of cassettes containing samples of various materials which had been exposed to the vacuum of space for a long period. The cosmonauts also retrieved the Soviet/French comet experiment which had been deployed during earlier Salyut 7 missions. The EVA was scheduled to last for three hours.

Kizim and Solovyov were actually performing an EVA originally intended for cosmonauts Vasyutin and Volkov. However, due first to the loss of radio signals with Salyut on February 11, 1985 and the subsequent need of a repair flight and then the curtailment of the extended flight of Vasyutin, Savinykjh and Volkov, the EVA was never accomplished.

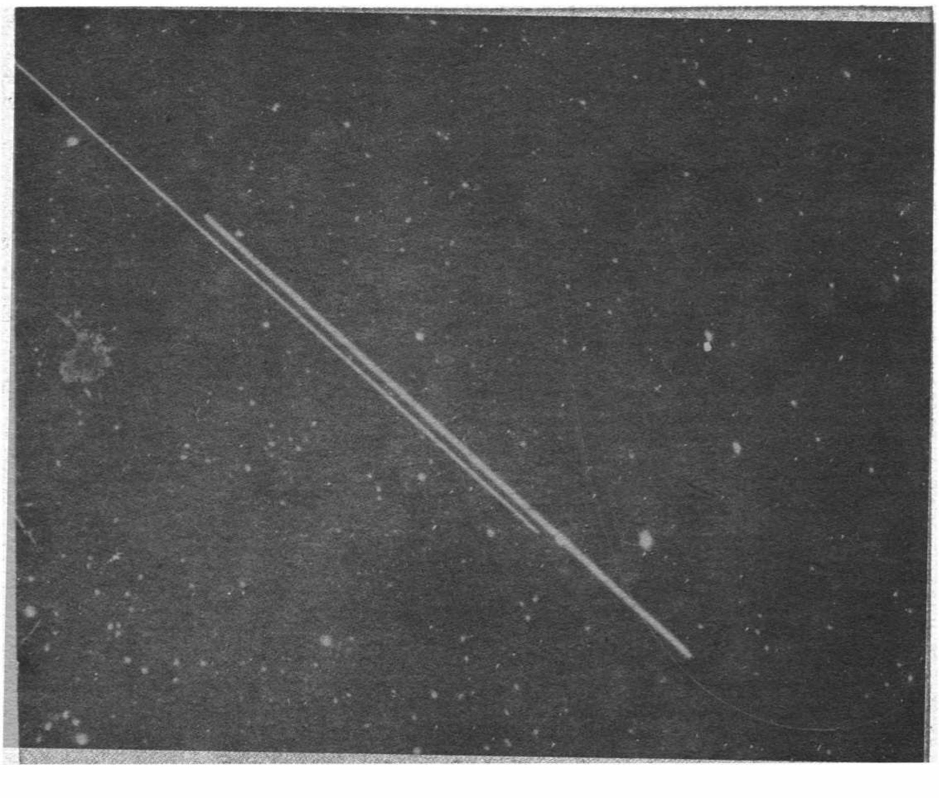
The major part of the work involved the deployment of a "girder" or "Truss" lattice and pin frame from a container called "Ferma-Postroitel". The container, some one metre diameter by one metre tall, had an Earth weight of 150 kg and was developed by the Paton Institute in Kiev.

The cosmonauts erected a mounting platform next to the hatch of Salyut 7 from which they had emerged and then attached the Ferma-Postroitel to it. The aim of the EVA, the Soviets said, was to test the deployment of the girder from the container in space conditions and to test its rigidity and stability.

There were three deployment options (manual, semi-automatic and fully-automatic) which the cosmonauts could select. The first deployment of the girder, a metal rhombus some 40 cm x 40 cm, was commanded automatically and the girder extended to a length of 15 metres. TV showed the cosmonauts at the base of the structure and the girder stretching away from Salyut against the Earth's blue and white curvature. The girder was then retracted.

Before returning to Salyut the men attached an instrument to a porthole of the station which TASS said was "intended for experiments related to the future transmission of telemetery information within the optical waveband". The EVA ended after 3 hours and 50 minutes.

An article in "Pravda" described a future version of the



The Salyut 7 space station and the Soyuz T-15 ferry vehicle are clearly visible as separate streaks of light across the night sky in this short time exposure taken on June 25, 1986 at about 22.30 UTC from Bonn, West Germany, by *Spaceflight* reader *Daniel Fischer*.

Soyuz T-15 had left the space station carrying cosmonauts Kizim and Solovyov only a few hours before and the exposure shows them orbiting some 4½ seconds of time (or five degrees) apart.

The direction of travel in the photograph is from bottom right to top left with Soyuz in front. Mr. Fischer also reports that less than five minutes earlier the new space station, Mir, had passed overhead in a similar orbit.

One orbit after the exposure was made Soyuz and Salyut were separated by 7½ seconds, with the Soyuz craft having faded in brightness considerably, possibly due to it being rotated.

This unique picture was captured using an SLR camera with a 50 mm lens at maximum aperture, on Tri-X film processed to achieve a speed of 1000 ASA. The brightest star belongs to the constellation Corona Borealis.

girder linking space settlements in orbit and the fact that the girder could be several kilometres long. The work was compared to the US Space Shuttle mission 61B assemblies EVA of November 1985 but on that flight the astronauts had assembled structures from individual portions whilst the Soviet EVA was using an automatic retractable device.

The cosmonauts spent the next two days working on documentation and cleaning their suits. The spacesuits were the same ones that had been used by Dzhanibekov and Savinykh the previous year for their five hour EVA.

On May 30 the Soviets announced that the cosmonauts were preparing for another EVA the next day. TASS said that, at 0645, Soviet TV would again begin broadcasting the EVA. At 0457 on May 31 the hatch of Salyut 7 was opened again by Kizim and Solovyov for them to start their unprecedented eighth EVA.

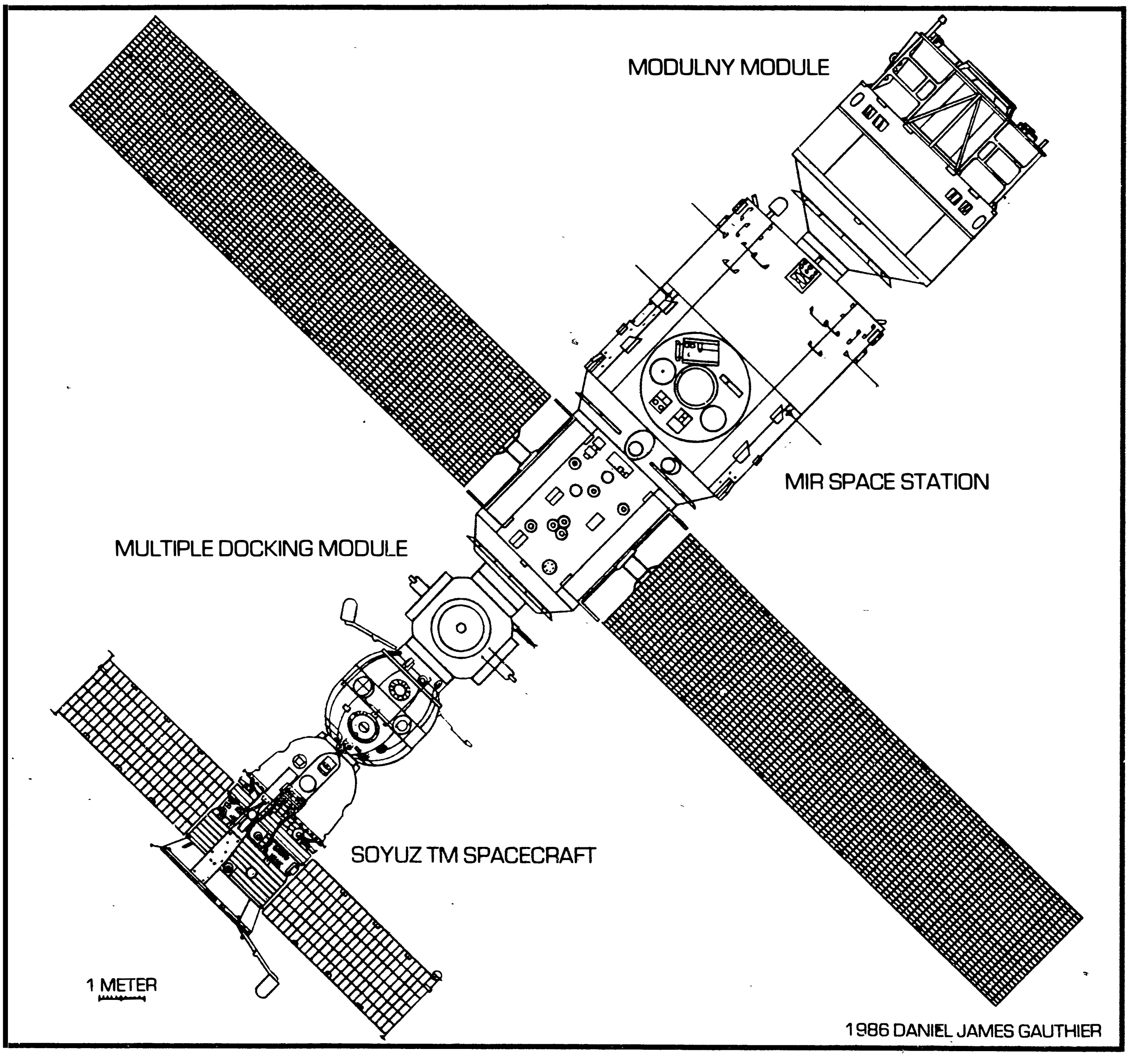
The cosmonauts' first tasks included mounting scientific equipment atop the girder which would be used to transmit information via a low-power laser to the receiver mounted near the porthole on Salyut. From there the data was relayed to Salyut's communications system and from there to FCC. The experiment – called LED – would start after deployment of the girder from its container. Another experiment, called "Fon", would monitor the "atmosphere" around the station once the girder was deployed.

The cosmonauts chose a manual deployment option for the second deployment, this time to 12 metres in length. During the unfolding a light beacon attached to the top of the girder was used as a reference point to look for oscillations. TV pictures showed Kizim floating along the lower half of the girder during the live TV broadcast. The Soviets noted during the broadcast that the device could be used to lift a cosmonaut above the station, if needed.

Kizim and Solovyov then removed a small fragment of a solar panel which had been left for testing over a long period and began tests of an improved version of the URI manual tool which had been originally tested by cosmonauts Dzhainibekov and Savitskaya on their EVA in July 1984.

Modifications to the URI included replacement of the crucible, used to melt metals for spraying onto the surface of a sample board, with an electron gun. Welding and soldering were also accomplished with URI on "typical girder structures" to test how to make the retractable girder rigid.

Kizim and Solovyov ended the EVA after five hours which brought each man's time in total EVA experience to 31 hours 40 minutes, far surpassing the record set by US astronaut Eugene Cernan. The EVA had been one more step towards building complex constructions in orbit, the Soviets said.



SOVIET SCENE

Return to Mir

On June 20 TASS reported that the Mir/Progress 26 complex had made an orbital manoeuvre and that refuelling of Mir's tanks was being completed. At 1825 on June 22 Progress 26 separated from Mir and the next day, at 1840, the engines of the cargo ship were ignited to send it to a destructive re-entry.

At the same time, the Soviets revealed that Kizim and Solovyov were "cocooning" Salyut's systems and were dismantling some of its equipment in readiness for a transfer to Mir. Soyuz T-15, TASS said, would separate from Salyut 7 on June 25.

On that day the cosmonauts, having finished all of their packing, sealed themselves into Soyuz T-15 at about 1300 and undocked at 1458 moving slowly away without using any propulsion. The Soviets said that the cosmonauts would conduct a "fairly complicated" docking with Mir 24 hours later.

There was no live coverage of the approach and docking with Mir. Kizim flew a semi-circle around Mir after the Igla automatic approach system had brought the spacecraft to some 50 metres of Mir. Kizim then approached the station manually and docked with an unspecified port at 1946.

Having spent 50 days before on Mir and 50 days on board Salyut 7 Kizim and Solovyov crossed over into Mir again on June 27. They had brought some 350 kg of equipment from Salyut including cameras and spectrometers.

The Soviets said that they would not reoccupy Salyut 7 "in the near future" although it would continue in orbit for "some more years". Soviets said that a revisit may be made to retrieve some part of the station for examination.

NEW DETAILS ON PHOBOS LANDER MISSION

Fresh information has now been revealed on the project for an unmanned mission to the Martian moon, Phobos. ***Brian Harvey,*** **in a supplement to his original report (see** ***Spaceflight,*** **March 1986, p 113), reviews the latest details.**

The spacecraft will fly into a circular orbit 30 km further out than Phobos at an altitude of 9400 km from Mars. The interception will take place on the sunlit Earth-facing portion of the orbit. A braking manoeuvre will take place, sending the spacecraft gently dirfting down towards the Phobos surface for the critical 15 minutes hover phase, until it returns to its circular orbital pattern.

Three key manoeuvres take place. First, two landers are dropped down to the surface. One is a static, long-life observatory designed to return a year's data. It carries a panoramic camera and other equipment to measure the chemical and physical properties of the surface. The second, smaller lander, is designed to hop around Phobos' low-gravity surface in kangaroo-like hops. This spacecraft has, informally at least, already acquired the title "kangaroo". Director of this project is Dr Georgi Managadzhe.

Second, the surface will be analysed by laser beam while the main spacecraft bus hovers 50 m above Phobos. Called LIMA-D, the Remote Laser Mass Spectrometer is prepared by the USSR, Bulgaria and West Germany, and weighs 70 kg. The laser unit will ionise and evaporate soil to a depth of 1 mm. The ions are scattered and then picked up by a reflectron. Each firing takes five to ten seconds.

Third, the surface soil composition will be analysed by ion beams. This experiment, weighing 18 kg, is called DION, and is assembled by scientists from Austria, France, West Germany and the USSR. An ion beam is injected towards the surface. Secondary ions, when scattered back, are received by a mass spectrometer. Each scan time will be one second. The purpose of the experiment will be to learn about the composition of the soil and solar wind elements implanted in the soil.

In the course of the hovering manoeuvre, a radar study of the surface will be carried out. This is an all-Soviet experiment called GRUNT. A radar is affixed to each of the spacecraft's solar panels. The experiment weighs 35 kg and radio sounding will take place to a depth of 200 m.

The interception of Phobos will be relayed by television. The survey, mapping, television, and spectrogram complex is called FREGAT and is an international unit made by scientists from Bulgaria, the USSR and East Germany. Three cameras will be carried.

The cameras will be switched on 6300 km from Phobos, when each frame will measure 3000 x 3000 km. Maximum resolution at interception will be six cm. The cameras will operate in conjunction with a spectrometer working to 14 spectral bands. 1100 frames will be recorded for onward retransmission. The cameras will use rotational mirrors in such a way as to get both wide and narrow angle shots. The wide-angle pictures are designed to photograph Mars in the background and the bright stars that are to be used for navigational purposes.

The radiometric package aboard the "Phobos" spacecraft is primarily designed for the study of Mars and the temperature of its surface. But it will be used during the Phobos interception to determine Phobos' temperature and soil composition. After that, its main function will be to search for permafrost regions on Mars and find sites of endogenous heat release.

The Phobos spacecraft will use a new design. It differs from the previous Mars and Venera bus in having Mariner-style solar panels and an apex Earth receiver. The engine unit will be discarded after the circular orbit is achieved.

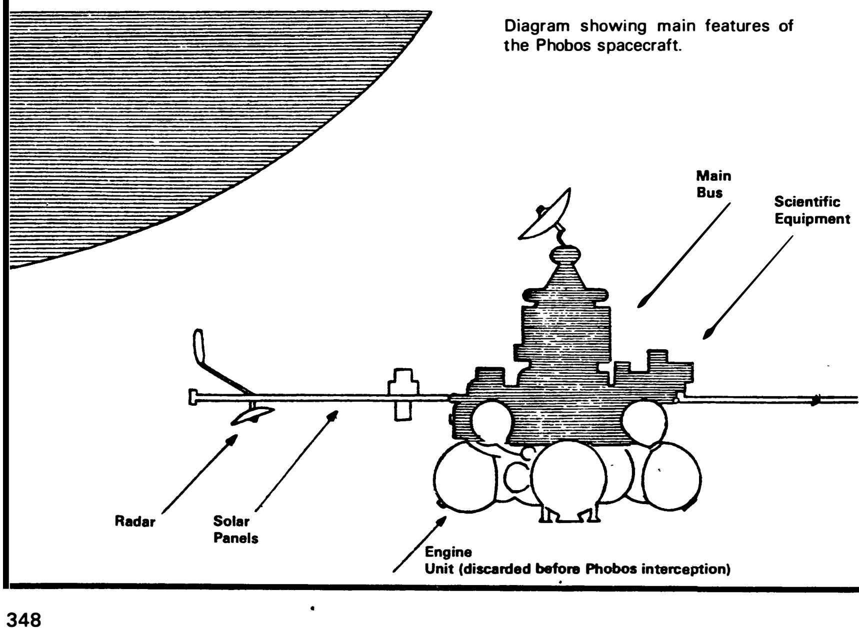


Diagram showing main features of the Phobos spacecraft.

SATELLITE DIGEST – 195

Robert D. Christy

Continued from the July/August 1986 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1742, 1986-33A, 16717.

Launched: 1240, 14 May 1986 from Plesetsk by A-2.

Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may have been carried at the forward end. The overall length was about 6 m, maximum diameter 2.4 m and mass around 6000 kg.

Mission: Military photo-reconnaissance, recovered after 14 days.

Orbit: 353 x 418 km, 92.32 min, 72.88 deg.

COSMOS 1743, 1986-34A, 16719.

Launched: 0427, 15 May 1986 from Plesetsk, by A-2 or F-2.

Spacecraft data: Possibly a truncated core with a pair of sun seeking solar panels at right angles to the centre of the body, and a sensor array at one end. The length is probably about 4 m, diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.

Mission: Electronic intelligence gathering.

Orbit: 633 x 655 km, 97.77 min, 82.56 deg.

SOYUZ-TM, 1986-35A, 16722.

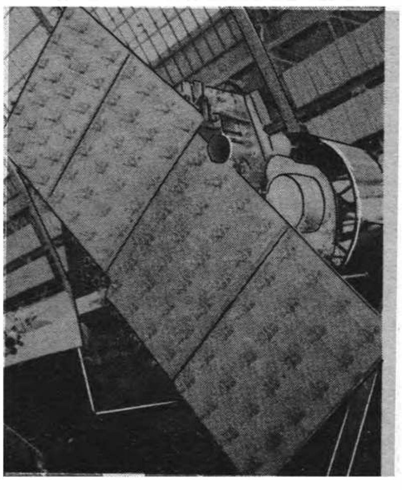
Launched: 0822*, 21 May 1986 from Tyuratam by A-2.

Spacecraft data: Near-spherical orbital compartment, possibly carrying a rendezvous radar tower, conical re-entry module and cylindrical instrument unit with a pair of solar panels, and containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.

Mission: Unmanned test mission of an enhanced design of Soyuz-T. It docked with Mir's forward unit at 1012 on 23 May, undocked at 0923 on 29 May, and returned to Earth on 30 May.

Orbit: Initially 195 x 224 km, 88.63 min, 51.61 deg, then manouevred to a 195 x 291 km transfer orbit prior to rendezvous with Mir in an orbit of 331 x 342 km, 91.22 min, 51.65 deg.

A model of the Ekran communications satellite which will be used for providing television and radio services to remote areas of the USSR.



COSMOS 1744, 1986-36A, 16724

Launched: 1630, 21 May 1986 from Plesetsk by A-2.

Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may have been carried at the forward end. The overall length was about 6 m, maximum diameter 2.4 m and mass around 6000 kg.

Mission: Materials processing payload, recovered after 14 days.

Orbit: 219 x 373 km, 90.44 min, 62.81 deg.

COSMOS 1745, 1986-37A, 16727.

Launched: 1255, 23 May 1986 from Plesetsk by C-1.

Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.

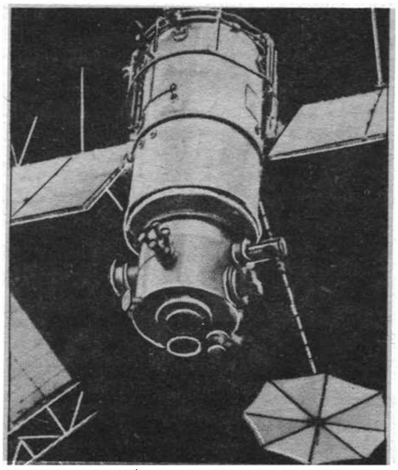
Mission: Navigation satellite.

Orbit: 968 x 1012 km, 104.96 min, 82.97 deg.

EKRAN 15, 1986-38A, 16729.

Launched: 0142, 24 May 1986 from Tyuratam by D-1-e.

Spacecraft data: Stepped cylinder with an aerial array in the form of a 6 m x 2 m rectangular panel at one end. Electrical power is provided by a pair of rotatable, boom mounted solar panels at the opposite end of the body, and positioned at right angles to it. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.



Soviet meteorological satellite with the sensor array clearly visible at the bottom of the cylinder.

Mission: Communications satellite providing television and radio services to community aerials in remote areas of the USSR.

Orbit: Geosynchronous above 99 degrees east longitude.

METEOR 2 (14), 1986-39A 16735.

Launched: 0932, 27 May 1986 from Plesetsk by A-2 or F-2.

Spacecraft data: A cylinder with a pair of sun seeking solar panels at right angles to the centre of the body, and a sensor array at one end. The length is probably about 5 m, diameter 1.5 m and mass around 2000 kg. Stabilisation is by the use of momentum wheels.

Mission: Meteorological and remote sensing satellite.

Orbit: 941 x 960 km, 104.13 min, 82.55 deg.

COSMOS 1746, 1986-40A, 16737.

Launched: 0750, 28 May 1986 from Plesetsk by A-2.

Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system, and a 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may have been carried at the forward end. The overall length was about 6 m, maximum diameter 2.4 m and mass around 6000 kg.

Mission: Photo-reconnaissance, re-entered after 15 days following a possible failed re-entry manoeuvre on 11 June. All or part of

the payload was an Earth resources package.
Orbit: 258 x 274 km, 89.89 min, 82.33 dep.

COSMOS 1747,1986-41A, 16745.
Launched: 0920, 29 May 1986 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may have been carried at the forward end. The overall length was about 6 m, maximum diameter 2.4 m and mass around 600 kg.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 211 x 256 km, 89.20 min, 70.36 deg.

COSMOS 1748-1755,1986-42A-H, 16758-16765.
Launched: 0358, 6 June 1986 from Plesetsk by C-1.
Spacecraft data: Each satellite is probably spheroidal in shape, about 1 m long and 0.6 m diameter, and with mass approx 40 kg.
Mission: Single launch of eight satellites to provide tactical, point to point communications for troops or units in the field.

Orbits: 1409 x 1471 km, 114.53 min, 74.02 deg (lowest) to 1468 x 1506 km, 115.74 min, 74.03 deg (highest).

COSMOS 1756, 1986-43A, 16767
Launched: 1240, 6 June 1986 by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several, small recovery containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and mass around 6000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 173 x 344 km, 89.70 min, 64.88 deg, manoeuvrable.

GORIZONT 12, 1986-44A, 16769
Launched: 0050, 10 June 1986 from Tyuratam by D-1-e.
Spacecraft data: Stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing continuous telephone, telegraphic and television links both within the USSR and abroad.
Orbit: Geosynchronous above 14 degrees west longitude.

UPDATES:

1986-22A, SOYUZ-T15 undocked from Mir at 1212 on 5 May. At 1658 on 6 May it docked with the rear port of Salyut 7. On 25 June at 1458 it departed again and returned to Mir with a docking at 1946 on 26 June. On 16 July at 1138 it returned to Earth with its crew.

1986-23A, PROGRESS 25 undocked from Mir at 1924 on 20 April and was commanded to a destructive re-entry shortly after.

1986-24A, COSMOS 1736 – the nuclear power source was separated from the satellite and boosted to a 925 x 1012 km orbit on 21 June.

1986-28A, COSMOS 1739 re-entered, possibly for recovery on 6 June 1986 after 58 days.

1986-32A, PROGRESS 26 undocked from Mir at 1825 on 22 June, and its retro rocket was fired at 1840 on 23 June.

JAPAN HALTS SOVIET RUN

While recent failures of US and European launch vehicles have temporarily halted Western space programmes, Soviet space activities continue unabated. During April, May and part of June, the total world-wide tally of spacecraft placed in orbit was 21 - all Soviet. Details appear in 'Satellite Digest' in the July/August and present issues of *Spaceflight.*

This sequence of all-Soviet launchings was ended by Japan with the launch of a relatively inexpensive 1500 lb experiment geodelic payload by that country's H1 booster on August 13.

Interest in the Japanese launch centres on testing the performance of the new oxygen/hydrogen upper stage.

COMMERCIAL LOSS FOR NASA

NASA could be excluded from America's official commercial space programme if a recommendation by a US Cabinet committee under the chairmanship of Treasury secretary James Baker is approved.

An early aim of the Space Shuttle programme was that it would one day recoup some of the costs of the Shuttle fleet from private satellite launchings, but with mounting costs and competition from the French-inspired Ariane and more recently from the Chinese Long March launchers, the US Government was already finding it hard to uphold the original aim, even before the Challenger disaster struck.

CORRESPONDENCE

US Space Programme

Sir, The US space programme has progressed from its inception by a continuing series of great leaps and bounds. In order to make ready for any particular leap, all offices have needed to be galvanised to the extent necessary to ensure the particular project gains sufficient momentum to see it through. In the majority of cases, some form of trailing-off, cutting-back or mission-trimming has manifested itself. Viewed in this light, the Challenger disaster was not, in itself, the cause of the present arrest of the American space programme but merely a very shocking symptom of the cause.

The Soviets have built up their abilities by adding, step-by-step to existing technology right from the start, both in rocketry and in other hardware: an example is the development from Salyut to Mir. Also, the cost of Mir is only a step up from the cost of Salyut, whereas the cost of any new departure by America is normally measured in megabucks. The cost element is only another symptom of the deeper problem.

The underlying differences between the US and Soviet programmes may well be due to the fundamental differences in their respective political systems, with the Russians not being prone to unsettling periodic changes in administration en-bloc. With the establishment of an agency such as NASA to administer the field, progress should have been smoother. Yet, we have a demand born of the Challenger disaster for even greater control and overseeing of NASA by the government, whereas it has been virtually acknowledged that one of the contributing factors to the disaster was the feeling of pressure to achieve a certain quantity of launches per annum.

Apollo, while brilliant, is recognised in an historical view as an expensive path leading nowhere. The Apollo period is when the Shuttle should have been developed. Now, instead of orbital platforms, the manned programme should be devoting itself to alternative advanced launching craft, such as Hotol or Reagan's belated "Orient Express", the arrival of which will greatly assist the permanent occupation of orbital space.

It seems to me that unless the United States can establish a clear, cool, long-sighted forward plan encompassing many goals by building directly and closely on previous work, which an agency such as NASA can adhere to regardless of any changes in national administration, then the US space programme will remain erratic.

P.W. MILLS
Kent

Soviet Shuttle Safety

Sir, The Soviet Shuttle is understood to have jet engines fitted as opposed to the US Shuttle's main engines, thereby allowing the Soviets to make another attempt if a landing went wrong.

In US Shuttle flights there is no means of escape from lift-off until after SRB separation two minutes into flight, unless the Orbiter were able to ditch in the sea.

If an incident happened with the Soviet Shuttle it would surely be possible for the Shuttle vehicle to pull away from its boosters and then have powered return to Earth, if necessary making two or more fly-bys before actually landing, or indeed be able to fly from the launch area to a safe landing strip.

T.K. BINNS
Kent.

Soviet Shuttle Test

Sir, It could be that Mr. Anderman ("Future Capabilities of the Soviet Space Programme", ***Spaceflight*** June 1986, pp. 249) has had his perceptions of probable Soviet space operations coloured by the way the United States has done things. He contends that because the USSR has troubled to modify the Soyuz T it is unlikely they will be launching their shuttle very soon. I feel that this is only an example of their practicality and resolve.

The American STS was the only manned vehicle in the US stable in 1981 and regular flights did not begin until 1983. It may be that the Soviets foresee a similar period of testing and refinement lasting years for their shuttle, during which they will use the Soyuz TM to ensure their access to space. They will not rely on their untested shuttle exclusively, as the United States chose to do.

It occurs to me that the Soviet Union might be able to conduct an uncrewed "all-up" launch-to-LEO test of their space shuttle system, something which NASA never had sufficient wherewithal to undertake. The destruction of 51L coupled with a new cautiousness in the wake of the Chernobyl accident might be expected to give Soviet planners the incentive to exhaustively test their system during the critical ascent phase. Their shuttle, without a crew aboard, would rise to orbit mated to an HLLV currently in the late stages of development to which would be strapped already-tested SL-X-16 boosters. Crew input has little to do with vehicle operations during the fast-paced ascent phase of the American STS, and it can be assumed such will also be the case with the Soviet shuttle.

Upon reaching orbit the Soviet shuttle could rendezvous with Mir or Salyut 7 and receive a thorough checking over in space. It might then be crewed for re-entry and landing on the long runway at Tyuratam.

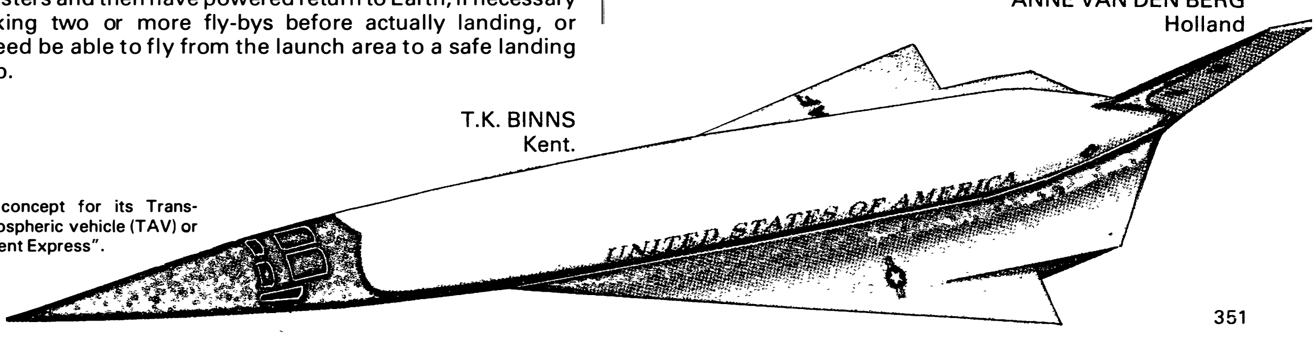
It seems to me also that the Soviet Union might see the launch of their shuttle as a golden opportunity to win back some of the technological prestige they lost in the Chernobyl accident. I expect them to launch their shuttle before the next launch of the American STS.

DAVID S.F. PORTREE,
Illinois, USA

Defence Payload Specialists

Sir, Another member of the unknown American DoD Manned Spaceflight Engineer cadre has been identified. The name of this Space Division military officer is Mike Booen. He was the backup to Payload Specialist Bill Pailes assigned to Shuttle 51J payload duties. Only four members of that group of about 25 persons are known: Gary Payton (Shuttle-mission 51C), Bill Pailes (51J), Mike Booen (perhaps eligible to be assigned to mission 61N, the next defence dedicated Shuttle mission with an open payload specialist seat) and John Watterson (assigned to fly on mission 62A, the first Vandenberg-launch of the Shuttle). Two other military offi-cers were rumoured to be members of the MSE-group: Hamel and Wright. However, no firm confirmation has been issued yet. Is there anybody who can help?

ANNE VAN DEN BERG
Holland



US concept for its Trans-atmospheric vehicle (TAV) or "Orient Express".

GEO before Moon with both Hotol and Hermes

Sir, I read with great interest Mr. Hartley's letter (Correspondence, June, 1986) in which he suggests that both Hotol and Hermes be adopted as ESA programmes with Hermes and an upgraded Ariane 5, or "Ariane 6", used for a European Moon mission. Although this type of mission is very appealing, it seems to me that there is another possible role for Hermes to play: a geostationary orbit shuttle. A modified Hermes shuttle with radiation shielding, etc., could be placed in geostationary orbit for approximately the same energy expenditure as the Moon mission, and would offer a good number of commercial advantages over a Moon mission, such as:

- Refueling, maintenance, retrieval and/or repair of geostationary communication satellites.
- Construction and servicing of large space platforms for commercial, scientific and communication applications with material brought up by Ariane 5 or 6. The large communication satellites being planned would greatly benefit from a construction and servicing capability.
- Building, maintaining, and supplying possible manned platforms in geostationary orbit.

This capability would place Europe on the vanguard of space; the USA does not presently have this capability and has no official plans that I know of to obtain it. In James E. Oberg's book *The New Race for Space,* H. Davis, of Eagle Engineering (Houston) points out that refueling and maintaining satellites in this manner would allow less-advanced satellites to be sold to customers with no need for the latest technologies. He also suggests that if high technology is the goal, modular satellite systems could be replaced with state-of-the-art equipment (e.g. radio transponders) and so kept up to date. And it should be noted that with a few hardware modifications, the Moon mission, or at least a Moon fly-by, could yet be easily accomplished.

The Hermes GEO shuttle could still be carried by Mr. Hartley's booster. While I do not know the payload capacity of his Ariane 6, in his letter he states that it could carry the Hermes and a two-stage lunar lander, which would have to weigh at least two or three tonnes. This could be the Hermes GEO shuttle payload; more than enough to carry several astronauts into orbit, a satellite and/or instrument pallet, or tools and perhaps materials to start building space platforms.

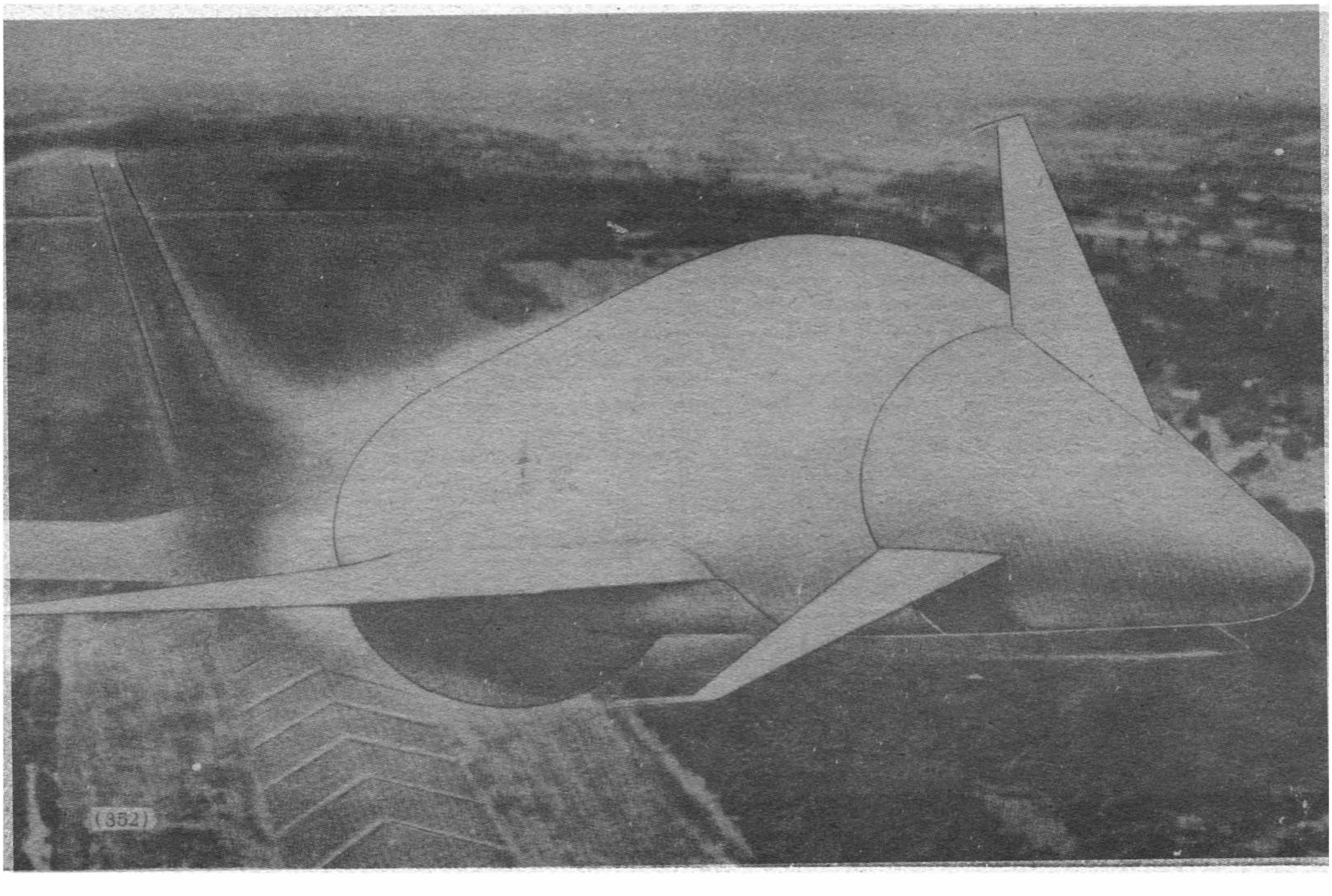
ESA could have a truly great space programme with a one stage to orbit spaceplane, a heavy lift launcher, a geostationary shuttle and possible space station, and an option to visit the Moon. The extra cost of developing both Hermes and Hotol, along with Ariane 5 and 6, would be offset by the commercial profit from GEO, and the Hermes' proven technology would assure the system's reliability. And then there are the "intangibles": a permanent beachhead in space and in GEO, platforms, possible breakthroughs ... and the capability to exploit GEO could literally create a market for Hermes where none existed before. A market already in existence would be that for "used" satellites, refurbished by Hermes and already in space, for Third World countries or corporations that could not afford them before. And from GEO it would be relatively easy to establish a permanent ESA presence on the Moon in the future.

But the decision must be taken as soon as possible, while the truly expensive commitments have not yet been made. The French will be more likely to support Hotol if it will complement, rather than supplant, Hermes. And ESA as a whole may be more willing to risk spending for both Hotol and Hermes if a clear commercial gain is apparent for both of them; something which a European Moon mission, while romantic, could not provide.

Besides, with ESA so firmly entrenched in space, how long will it be before we see the first European manned Mars mission? It would no longer take a Herculean effort.

ALVARO FERNANDEZ
Florida, USA

Hotol takes off from a conventional runway on its way into orbit in this artist's representation by ***Arthur Gibson.*** *BAe*



CORRESPONDENCE

Hotol Cost Prediction

Sir, I reply to "Hotol Economics" (***Spaceflight***, July/August 1986, p. 305) as follows:

1. No reasonable cost prediction is possible regarding essentially new (not marginally improved!) technology.
2. Much of Hotol cost prediction rests on the Transcost Model, which was developed largely under my direction, so I know. It is not applicable to items like Hotol being essentially interpolative between similar items.
3. All "official" cost predictions for Shuttle were miserably wrong (optimistic); the best were Val Cleaver's and mine which were still optimistic by about a factor of two on taking our "pessimistic limits". And the Shuttle was "less novel" than Hotol would be.
4. As with all single-stagers, Hotol's performance is very sensitive. About 41 T are orbited, of which only 7 T are payload; and a mass growth of ca. 20 per cent leaves no payload, even if all other performance parameters are as desired.
5. Enough of Hotol's propulsion system is known by now that I do not believe that this performance can be realised within the mass budget allowed for.
6. Hotol's structure is impossible with present-day technology. With new technology, time and cost schedules are wishful thinking, being somewhat comparable to making such schedules for Project Daedalus.

Research towards Hotol (and comparable space transport candidates) might realistically be initiated. Even that I would think is now too early to do, but this clearly is a matter of opinion.

To Mr. Westman who writes on Hotol in the same issue of ***Spaceflight***, I say that the argument is not desirability; it is achievability.

HARRY O. RUPPE
Munich

Dr. R.C. Parkinson has been invited to respond to Prof. Ruppe's letter and writes as follows:

Sir, The readiness of technology to meet future launcher requirements is a key issue in establishing the viability of the system. With its National Aerospaceplane programme, the US demonstrated that it is prepared to pursue research towards high performance single-stage to orbit vehicles in a characteristically aggressive fashion, with the intention of having such a space vehicle to follow the Space Shuttle. The US obviously believes that such technology is not out of reach. The intention with Hotol is to operate in a far less demanding flight envelope and so avoid many of the problems inherent in the Aerospaceplane project. Our current studies are intended to establish that the techonology required is in fact no more than marginally improved over that available today in, for example, the E.F.A.

Hotol cost prediction does *not* rest on the Transcost model but on British Aerospace modelling systems which go back as far as 1965 and the Mustard programme. We have been at some pains to establish that the costs being produced are realistic when compared with currently available information, but it is significant that the Mustard cost prediction for the Shuttle, when inflation is taken into account, gave the correct value within 1.5 per cent. Our current cost estimates for Hotol are based on a significantly greater "in depth" cost analysis than available with the Transcost model and confirms our early opinions of the economic attractiveness of Hotol.

There is still a great deal of work to be done before Hotol can become a European successor to Ariane but our optimism is based on hard engineering analysis and not wishful thinking.

R. C. PARKINSON
British Aerospace

SETI in Question

Sir, The Fermi paradox has become the central question of SETI, which Dr. William McLaughlin phrases as 'Where are the hominid-like extraterrestrials?[1].

Perhaps the answer to Fermi's paradox lies with the evolutionary biologists' objections to SETI which have been so persistently ignored.

Since at least the time of Aristotle, biologists have recognised that a fundamental biological relationship exists between any creature's 'structure' and 'function', ie in between its body form and its behaviour. They are not independent.

So central is this to evolutionary biology that it has profound consequences for any notion of 'hominid-like extraterrestrials'.

SETI supporters accept the extreme improbability of duplication of the humanoid body form. However, this reasoning is not applied to 'humanoid' intelligence. Since 'humanoid' intelligence logically implies 'humanoid' behaviour, one would not expect 'humanoid' intelligence to be coupled with an alien body form. Yet SETI argues exactly this.[2].

This objection is not, however, a minor one. What it does highlight is the logical confusion that SETI rests upon. If extra-terrestrials exist, of whatever kind, they will be unlike anything we have ever known: neither flowering plants, vertebrates, arthropods, or any other terrestrial group we are familiar with. They will be completely alien.

Biological convergence has often been called upon to bolster SETI, yet the most commonly utilised example, namely convergence in fish, dolphin and extinct ichthyosaur, actually contradicts the very thing it is supposed to support.

This example of bodily convergence implies behavioural convergence, though SETI argues the complete antithesis of this: that 'humanoid' behaviour can evolve in a totally unrelated and evolutionary distinct body form [3]. A variety of other objections could also be made and are discussed in greater detail in Ref. 3. How does all this relate to the Fermi paradox?

The SETI approach entails the 'design' of a hypothetical creature, combining 'humanoid' intelligence with an alien body form. It is not, in any way, an evolutionary model. Instead, it is quite arbitrary, ignoring as it does the basic and absolutely central biological principle that body and behaviour are inextricably intertwined. Both will thus evolve in tandem. Consequently, an alien body form will signify alien, not humanoid, behaviour.

The importance of this biological argument lies in the fact that the Copernican principle is just not implicated in it at all. Clearly, the methods and approaches of the evolutionary biologist, and the physical scientist, are not synonymous. Hence, the evolutionary claim that humans are unique, without duplication, is not chauvinism but a recognition of the improbability of repetition of a 'humanoid' evolutionary pathway.

As surprising as it may seem, it is more likely that an alien creature without intelligence can acquire technology than that 'humanoid' intelligence would evolve elsewhere.[4]. The answer to Fermi's paradox is not that extraterrestrials do not exist, just that 'humanoid' or 'hominid-like' extraterrestrials do not.

E. J. COFFEY
London

REFERENCES

1. W. McLaughlin, 'Where are they?',***Spaceflight***, 28 235 May 1986.
2. C. Sagan, 'An Introduction to the Problem of Interstellar Communication,' in Interstellar Communications, (eds) C. Ponnamperuma & A.G.W. Cameron, Houghton Mifflin, Boston, 1974.
3. E. J. Coffey, 'The Improbability of Behavioural Convergence in Aliens, ***JBIS***, 38 515 Nov. 1985.
4. D. M. Raup, 'ETI without Intellig··.ce, in Extraterrestrials, (ed) E. Regis, Jr., Cambridge University Press, 1985.

Spaceflight

30th Anniversary Marked by Bookstall Launch

An Appreciation by Arthur C. Clarke

With this issue, *Spaceflight* enters its 31st year of continuous publication – an event that warrants more than a mere mention in Society News. So please read on. This is a time not only to look back over the last 30 years but also to the future. But first, what of the past? Volume 1, Number 1 of *Spaceflight* appeared in October 1956 under the editorship of Patrick Moore.

In his first ***Spaceflight*** editorial, Patrick wrote "The spreading of correct information is one of the Society's chief aims. ***Spaceflight*** is a new venture ... to give readers a picture of the research going on, as well as discussing related matters. So much research is now in progress that each issue is certain to contain new information." The early days of any new publication are always the most crtitical. ***Spaceflight*** was well nourished by the inflow of news and the writings of contributors – and survived!

Although in 1956 the Space Age had yet to dawn, the stage was already set. A message of good wishes to the new ***Spaceflight*** from Frederick C. Durant III, the President of the International Astronautical Federation, was published in the first issue. He wrote: "With the first satellite vehicles to be launched in the next few years, there is every indication that man will travel in satellite flight within a decade. I predict a successful future for your publication and believe that it will fill a real need". Fred was right on all accounts.

Now what of the future? Members have asked for many years about ***Spaceflight*** appearing on the bookstalls. This would indeed provide a great opportunity for a wider public appreciation of developments in Space and the Society's work. When the question arose about how best to celebrate ***Spaceflight***'s 30th anniversary, there could be only one answer. This September/October issue will therefore be available through UK bookstalls and newsagents from mid-September and subsequent issues will likewise be distributed according to demand. These arrangements will in no way affect the dispatch of ***Spaceflight*** to members which will be by postal delivery in advance of any other means of distribution.

Spaceflight begins its second 30 years with new horizons in sight and the determination to maintain the standards and traditions of its past. With the continued support of its many contributors and readers, the future looks bright. Congratulations and good wishes for ***Spaceflight***'s continued success.

Arthur C. Clarke,
Chancellor, University of Moratuwa,
Sri Lanka,
Honorary Fellow and Past President,
British Interplanetary Society.

Arthur C. Clarke.

SPACE ART

A packed audience at BIS Headquarters heard Britain's leading space artist, David A. Hardy, give a superbly illustrated talk on space art on May 14. He started with fifties-vintage impressions of the Moon by R.A. Smith of the BIS and by the Grand Old Man of space art Chesley Bonestell. Those were the days when moon-rockets had wings and the lunar mountains had needle-sharp peaks. The only artist to anticipate the actual rounded shapes of the lunar mountains was the Frenchman Lucien Rudaux 50 years ago. Mr. Hardy also included an interesting early painting of his own showing the BIS lunar spaceship nearing the Moon.

Turning to more recent space hardware, he included some paintings by Sokolov of Soviet exploits and, in the full spirit of his title "Artists in Space", a self-portrait of Alexei Leonov outside Voskhod 2. The major part of his talk was an illustrated tour of the Solar System with work by present-day space artists such as Don Dixon, Ludek Pesek and Bob McCall compared with NASA images of the same subjects. Saturn with its rings, viewed from every conceivable angle, was naturally the most popular subject. A look at some of the possibilities outside the Solar System, with many artists finding inspiration from unusual binary stars such as Epsilon Aurigae and Beta Lyrae and, more recently, black holes, brought the talk to a spectacular conclusion.

G.R. Richards

Obituaries

Chesley Bonestell

Chesley Bonestell, the internationally famous artist of astronomical and space scenes and Member of the Society since 1949 died on June 11, 1986 at his home in Carmel, California. He was 98 and is survived by his wife, Hulda, and a daughter.

During his long life he had three successful careers. In his early days he studied architecture and worked on major structures, including the Golden Gate Bridge in San Francisco and the Chrysler Tower in New York. In 1938, at the age of 50, he began a second career as a motion picture special effects artist and within a few years became much sought after in Hollywood for his skill in creating realistic scenes.

In 1944 he embarked on his best known career as a space artist and, until his death, painted nearly every day in his studio. During the first ten years he created some of his most compelling works in the form of illustrations of manned visits to the Moon and planets. This was a decade before the advent of large rockets and satellite flight and before space flight was professionally acceptable – or even respectable.

Bonestell's ground-breaking space illustrations appeared in major publications, including: *Life, Look, Scientific American, Astounding Science Fiction.* He collaborated with Willy Ley, a founding member of the German Space Travel Society and the author of the classic *Rockets, Missiles and Men in Space.* Ley and Bonestell produced *The Conquest of Space* (1949) and *Beyond the Solar System* (1964). Teaming up with Wernher von Braun and others, they brought out *Conquest of the Moon* (1953), and Arthur C. Clarke and Bonestall toured the planets in *Beyond Jupiter* (1972).

In the early 1950's *Collier's* magazine asked him to illustrate a technical series of articles, to be written by Wernher von Braun, astronomer Fred Whipple and others. During the next few years, Bonestell illustrated several more major articles for *Collier's* on themes such as space station, the training of astronauts, and a manned expedition to Mars.

These articles acted as a catalyst, encouraging discussion and debate among engineers and scientists. Was space flight feasible, or was it just a romantic adventurous dream? Were there economic benefits to be gained? Was it worth the money? While theorists argued about the possibility of rockets and spacecraft travelling to the Moon and planets, Bonestell showed what it would look like when we got there! His paintings are now scattered round the world in private collections and public displays.

Mr. H. E. Dall

Mr. Horace Edward Dall, a member of the Society since 1957, died in early May at his home in Luton, Bedfordshire. He was 85 and leaves a widow and three step-children.

He moved to Luton at the age of 14 to be apprenticed to an aircraft manufacturer and his mathematical skills were quickly recognised and nurtured by hours of study at night school.

While still a young man in his 20s he achieved nationwide fame for his daring and unusual travels. He crossed the Atlas mountains in North Africa on a bicycle at a time when the French Foreign Legion was still fighting to control the region, and was briefly captured by hostile tribesmen.

He made pioneer trips across Greenland and Lapland, and a few years later toured the world on a scooter.

Back in Luton he worked for engineering firm George Kent, eventually rising through its research department to become senior flow development engineer, exploring the possibilities of velocity, pressure and motion.

It was in this capacity that he first achieved international recognition, winning many professional plaudits, carrying out innovative work on nuclear power and, during the war, performing vital examinations of German secret weapons like the V2 rocket.

But he also counted the whole universe as his hobby and won worldwide regard as an amateur astronomer.

His home, named Long Vue, was equipped with a purpose-built observatory as well as one of Britain's few camera-obscuras, and his knowledge of the geometry of optics enabled him to design and build his own telescopes and microscopes, grinding his lenses to within millionths of an inch.

He put his name to the Dall-Kirkham system of building telescopes, was a former Vice President of the British Astronomical Association and was greatly involved in sky-watching groups locally, nationally and internationally.

After the death of his first wife Vivien, and his retirement from Kents in 1965, Horace Dall returned to his travels.

Three years later, at the age of 67, he met his second wife Helena, now 82, when they crossed paths in Patagonia. He was about to travel down the Amazon and she was crossing the Andes by land.

MEETINGS DIARY

All meetings unless otherwise stated are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ.

4-11 October 1986 **Congress**

37th IAF CONGRESS

The theme of the 37th International Astronautical Congress is "Space: New Opportunities for All People" held in Innsbruck, Austria, at the invitation of the Austrian Solar and Space Agency.

Registration details can be obtained from the Secretary.

29 October 1986, 7-9 p.m. **Lecture**

COSMIC IMPACTS

by Dr John Davies

There are about 1000 objects more than one kilometre in diameter in Earth-crossing orbits, and occasionally these celestial projectiles strike our planet with tremendous force. This illustrated lecture will reveal evidence of ancient

collisions with the Earth, and discuss the geological and environmental implications of a major cosmic impact.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

19 November 1986 **Symposium**

SPACE TRANSPORTATION: HOTOL

A one-day symposium on the proposed British Aerospace/ Rolls Royce horizontal take off and landing vehicle. Potential authors should contact the Executive Secretary. Registrations details available on request.

26 November 1986, 7-9 p.m. **Lecture**

FUTURE BRITISH SPACE POLICY

by Dr. T.L. Roberts
Director of Planning and Finance BNSC

On the first anniversary of the formation of the British National Space Centre, Dr. Roberts reviews progress and gives an insight into British Space policy.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

4 December 1986, 6.30 - 9 p.m. **Visit**

SCIENCE MUSEUM
– to celebrate opening of new gallery

A special visit by Society members to the Science Museum in South Kensington has been arranged. The programme will provide an opportunity to view the new Space Gallery and see extracts from two vintage space films 'Things to Come (1936) and 'Frau im Mond' (1929).

A contribution of £5.00 will be charged per member to cover the cost of a buffet with wine which will also be provided during the course of the evening.

As the party will be limited in number, advance registration is essential. Forms are available from the Executive Secretary.

The Soviet Cosmonaut Team

G.R. Hooper, GRH Publications, 36 Bury Hill, Melton 1025, Woodbridge, Suffolk IP12 ILF. 336pp, 1986, £10.85.

The author has attempted to cover the first 25 years of the Soviet manned space programme by bringing together all available information on the history and composition of the Soviet Cosmonaut Team, together with comprehensive biographies of each Cosmonaut involved, space assignments, time spent in space, etc.

To achieve this aim the book divides into two main parts. The first analyses various aspects of the Soviet manned space programme in detail, with comprehensive listings given for each crew. The second consists of illustrative biographies of every Soviet and Intercosmonaut, including the two Syrian candidates, and concludes with a brief note on some of the men named in Soviet Reports as trainee-cosmonauts who have not yet flown.

Mars – Our Future on the Red Planet

R. M. Powers, Houghton Mifflin Company, Two Park Street, Boston Massachusetts 02108, USA. 1986, 230pp, $17.95.

The concept of a manned expedition to Mars is one which both catches the imagination and becomes more feasible with each passing year.

In this book the author theorises on what it would be like to make the voyage, to land on a new world and to establish a tolerable habitat for humans. He also looks to the more remote future on the matter of terraforming i.e. altering the Martian climate to allow not only substantial human settlement but a place where colonists will prosper.

Although matters of this sort receive detailed attention, problems inherent in the design, construction and similar factors concerned with the fabrication of a spacecraft able to make such a journey and return safely are not dealt with in depth: the book tends to concentrate on the ends rather than the means. This may be justified on the grounds that imagination must exist before it can be converted to reality, but a simple statement such as "A hundred NASA engineers have designed manned vehicles that could reach the Red Planet" is hardly likley to appeal to those on whom the onus for developing suitable spacecraft may one day fall. To some extent this is reminiscent of accounts of travel to the stars which pay slight attention to the technological factors involved.

Even so, the case for an expedition to Mars, its scientific and other achievements, has to be made and in this respect the author has presented his case with enthusiasm and gusto.

This is a well written book, likely to stir the imagination and appeal to all who long for ambitious steps in space, even if, unfortunately, the road proves to be longer and harder than many supposed.

Jane's Spaceflight Directory 1986

Reginald Turnill, Jane's Publishing Company Limited, 238 City Road, London EC1V 2PU. 453pp, 1986, £62.

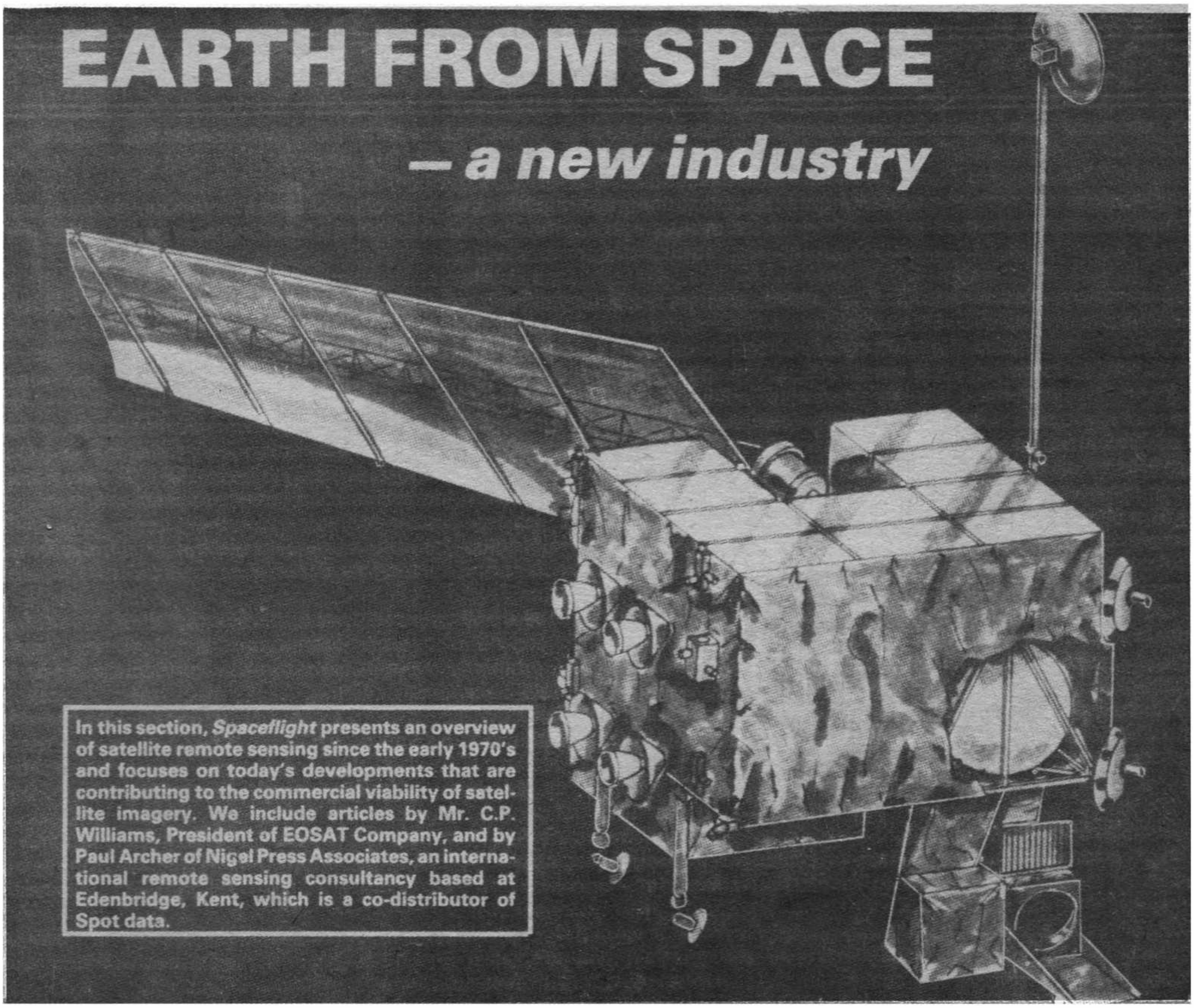
This is the second edition of a space directory which has already secured a place as a major work of reference and which is now due to appear annually. It records every significant national and international space programme from Sputnik 1 to the Space Station, as well as the latest information available on Soviet space activities.

Guide to Observing the Moon

British Astronomical Association, Enslow Publishers, PO Box 38, Aldershot, Hants, GU12 6BP. 1986, 128pp, £9.95.

This book, prepared by leading members of the British Astronomical Association, provides a comprehensive guide to techniques for observing the Moon. Besides presenting general principles, it describes the kind of equipment to buy or make, how to use it and how to draw Lunar features and/or take Lunar photographs, as well as adding a general description of the Moon's photometric and colourimetric properties.

Two programmes in which amateurs can make observations of great value are concerned with occultations and transient Lunar phenomena. Directions are given on how to participate in these.



The Omnistar/Landsat 6 polar platform which will offer continuity of Earth observtion satellite data to the year 2000 *ESOC*

Opportunity for UK

Two years ago the US government decided to 'denationalise' that part of its civilian space programme concerned with observing the Earth's surface from Space. This led, in September 1985, to the formation of the Earth Observation Satellite Company (EOSAT) to take over existing operations and provide a commercially viable service.

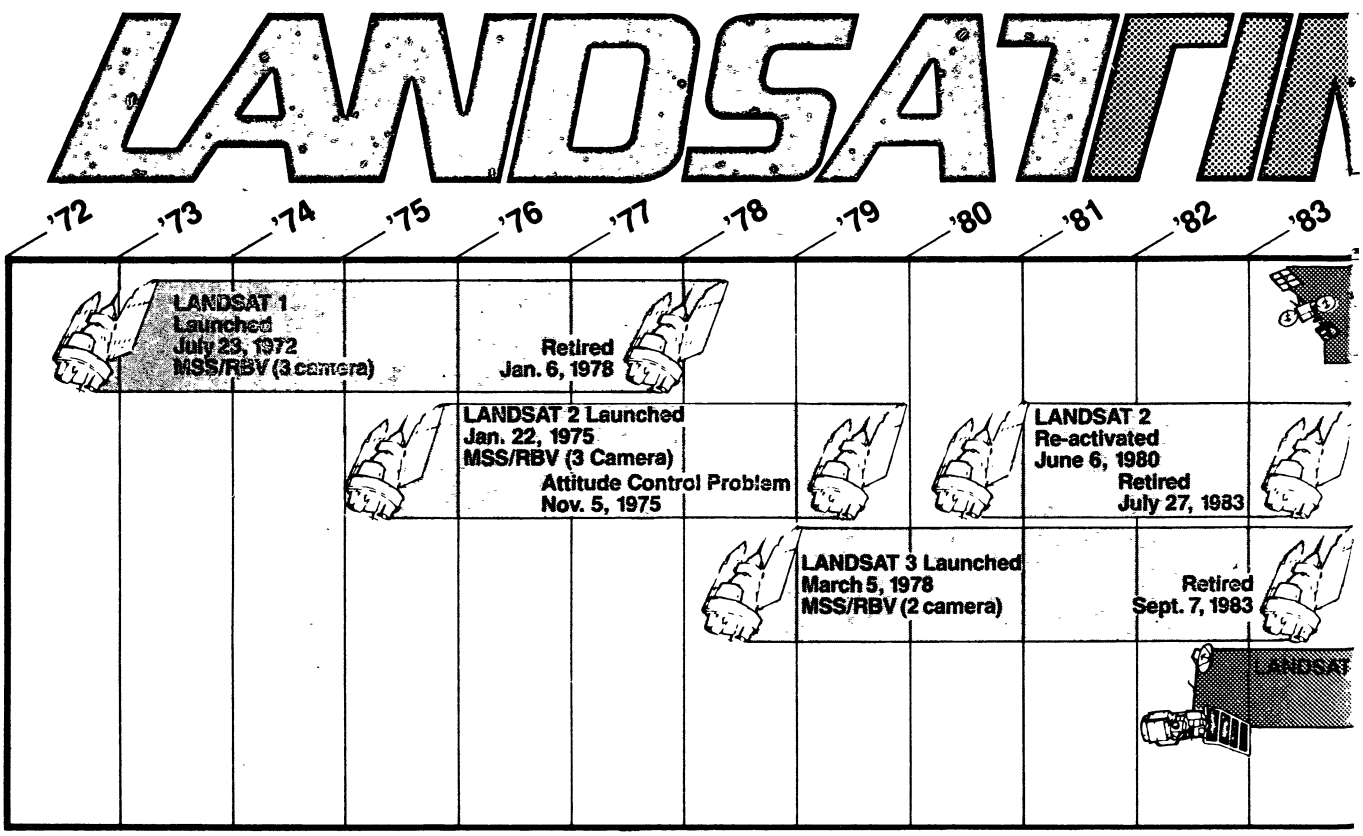
On February 22, 1986 France's civilian Earth observation programme reached an important landmark with the launch of its Spot-1 (Systeme Probatoire d'Observation de la Terre) satellite after eight years of technical development (***Spaceflight***, June 1986, p. 257). The launch of Spot-1 marks the beginning of a new phase in commercial space operations. The private consortium Spot Image, formed in July 1982, is the commercial operator for image marketing and distribution in association with the French national space agency CNES which is responsible for the operation of the satellite and follow-on programmes.

Problems arising with the commercial production of satellite imagery are similar to those facing any new industry. A key area is that of stimulating the overall product market. New potential users in government agencies, private companies and education need to appreciate the value of satellite imagery to their particular concerns. At the same time the raw image data need to be processed to suit users' technical requirements – and also the size of their pockets.

In Britain, the Government's primary space objective has been to promote the development of profitable industrial and commercial organisations capable of producing and exploiting space hardware, software and services. The British National Space Centre (BNSC) has recently reviewed UK space activities and prepared a National Space Plan which now awaits Ministerial approval. Existing resources, such as the National Remote Sensing Centre (NRSC) which was formed on April 1, 1980 at the Royal Aircraft Establishment, Farnborough, Hants, are to be co-ordinated in ways that will enhance the commercial viability of satellite imagery and establish a new national asset. On June 9, 1986 a contract was signed between the BNSC and Spot Image that will enable the NRSC to distribute data from Spot-1 of UK scenes (***Spaceflight***, July/August 1986, p. 293).

The UK has a high international profile in computer software and a long-established involvement in global surveys, both of which lead naturally onto the processing and applications of satellite imagery. Active participation is needed in all aspects of satellite remote sensing – hardware, software and services – including a UK remote sensing satellite. The National Space Plan, which can be expected to be announced within the next month, should be capitalising on this area of UK expertise with bold new commitments for the next decade.

Comment



Space Remote Sensing

"Among the newer dreams is that of a revolutionary global observation system, international in subject, participation, and service. It would meet the needs of the entire world in concert with the finest traditions and highest aspirations of the space programme. The peaceful daily observation of the Earth's atmosphere, oceans, and land from a polar platform – provided through international cooperation and tended by a multinational crew of astronauts – is one of the dreams of the space age. While today it is only a dream, it is a dream worthy of being realised."

John McElroy

by C. P. Williams *

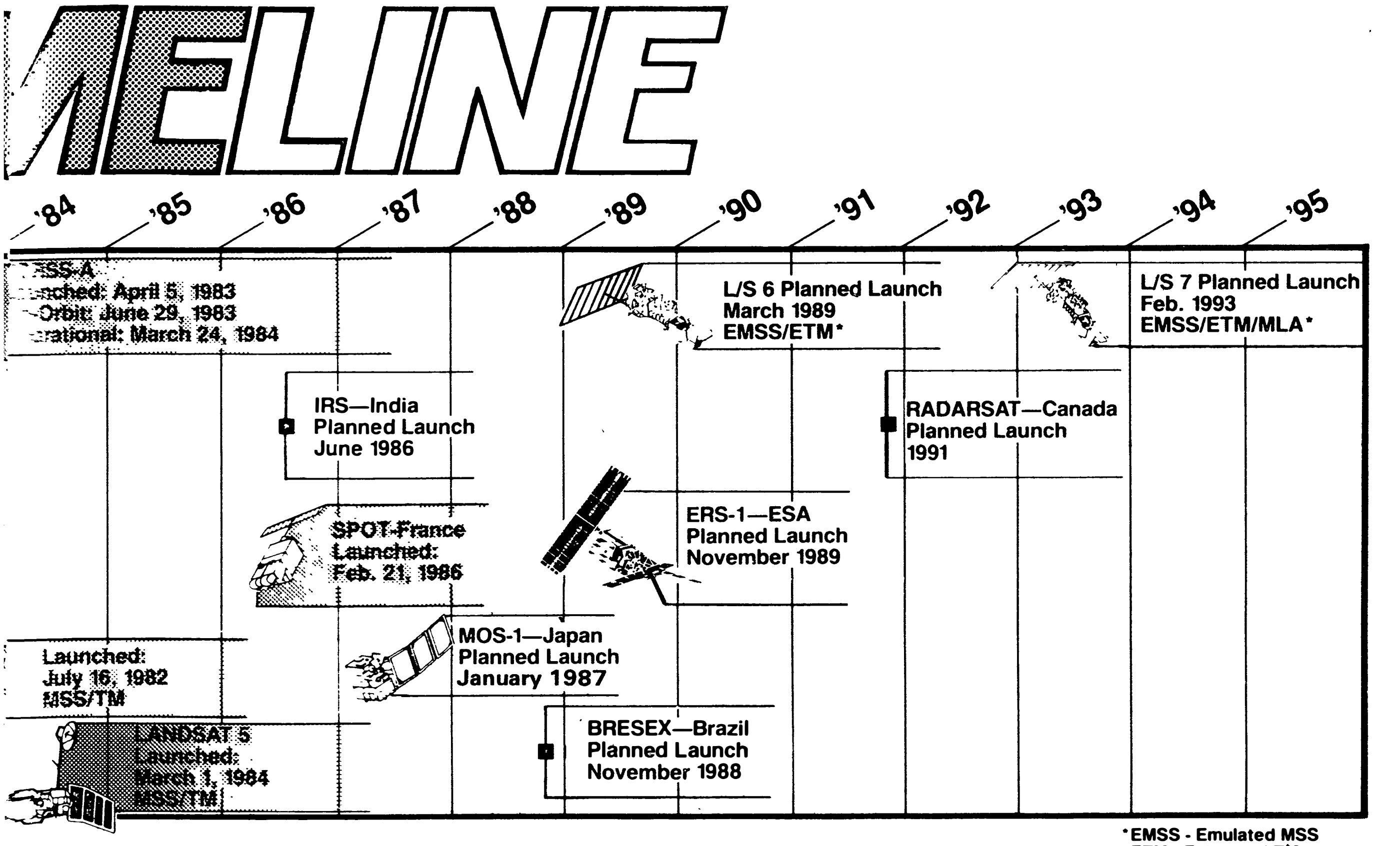
The US Land Remote Sensing Programme (Landsat) has produced images of the Earth from space since 1972. The fulfilment of man's desire for knowledge of the Earth's resources has an extensive history and continues as the technological advances in satellite remote sensing bring new information to the scientist from new commercial satellite programmes. Using the OMNISTAR polar-orbiting platform, the Landsat programme will continue to develop capabilities in remote sensing into the next century with more flexible instruments and multi-mission payloads to enhance this world-wide resource.

Background

Land remote sensing by satellites today represents the fulfilment of a dream of viewing the Earth from space that men have had for the past 200 years. Significant developments during this time have included:

- The use of a hot air balloon to capture Tintype images of a small village outside Paris. Through his aerial imagery, Nadar began a mapping revolution through-out the world.
- Aerial photography and photogrammetry which flourished because of the military reconnaissance needs of many countries.
- Cameras mounted on low Earth-orbiting rockets which returned imagery that scientists found scientifically intriguing due to their information content and which were also immediately useful for land and cloud mapping.
- The beginning of man's use of outer space as a vantage point for Earth mapping and monitoring of the Earth's atmosphere, from April 1, 1960.
- Manned Apollo missions which returned imagery as multi-band photography that challenged man's imagination to expand our ability to monitor the Earth from space.

*President, Earth Observation Satellite Company.



*EMSS - Emulated MSS
ETM - Enhanced TM
MLA - Multiple Linear Array

The Landsat Series

The Earth Resources Technology Satellite (ERTS), later renamed Landsat 1, launched in 1972, was the logical outgrowth of man's space experimentation of the 1960's and the beginning of a series of Landsat spacecraft which continued through the 70's and into the present day providing coverage of the Earth that was usable for tracking and managing both renewable and non-renewable resources. The areas that will be directly affected by changes in remote sensing over the next few decades include geology, hydrology, land use/urban planning, agribusiness, forestry, cartography, bathymetry, meteorology and oceanography.

By executive decision, the Landsat programme was transferred to the private sector in September 1985. The Earth Observation Satellite Company (EOSAT) took over operation at that time of the current Landsat satellites and initiated a programme to build new satellites and an operational ground system.

At present Landsat 3 is holding orbit and is partially operational. Landsat 5 is fully operational and is estimated to continue to function until 1988.

Landsats 6 and 7 are under development by EOSAT utilising an enhanced thematic mapper (ETM), built by Hughes Santa Barbara Research Center, as the basic land remote sensing instrument. The ETM contains seven spectral bands (from 30 to 120 metres ground resolution), a 15-metre panchromatic band, and an option for 60-metre IR bands.

The basic spacecraft design chosen for Landsats 6 and 7 is the "Omnistar" long life platform designed by RCA's Astro-Electronics Division. This platform provides a long life, flexible design for Shuttle launch, retrieval and in-orbit refurbishment and/or component replacement. The platform, with instruments and subsystems designed for a minimum of five years in-orbit life, can provide up to 20 years of data continuity for users throughout the world. High platform throw-weight provides excess capacity for additional instrument payloads and smaller developmental payloads. This type of platform with varied instrumentation will be typical of the platforms designed and developed early in the 21st century.

Other Programmes

Remote sensing from space, whether it be for land, ocean, environment, or whatever application, is becoming a major element in the space programme planning and implementation for large nations throughout the world. Over 5,000 data capture stations over the world receive weather data either directly or indirectly from US satellites today. Europe, looking to its own independent needs, has a low-polar orbiting meteorological platform programme in development which will provide data from state-of-the-art instruments to the year 2000.

The US Landsat programme operated now by EOSAT looks toward providing land remote sensing data to the year 2000 as a minimum. US Landsat data is currently used by over 80 countries throughout the world and directly downlinked to foreign ground stations in 13 countries.

Other major programmes are the French Spot Image land remote sensing satellite programme with a planned 15-year lifespan which is based upon two and four year design-life satellites. The French plan to downlink directly to 20 countries and already have their first satellite with 10 and 20 metre resolution instrumentation, in operation. The European Space

Agency (ESA) and the Japanese are planning their own remote sensing missions which will be initiated in the 1988-1992 timeframe and carry through the year 2000 utilising multiple instrument suites.

Cooperative planning, data use, standardisation of hardware, software, data formats and communication frequencies have already been initiated by many world bodies or groups such as NASA and NOAA (National Oceanographic and Atmospheric Administration) in order to maximise limited resources and emphasise international cooperation, not competition.

Prospects For The 21st Century

The prospects for the twenty-first century in remote sensing from space seem from a scientific point of view to be almost unlimited. Yet, we have to consider the constraint of time and budget on the logical development of new operational elements, systems and programmes. However severe the budget and resource pressures are now, it will not be any less severe 40 years from now. A growing need from this point in time on is for cooperative or joint venture type programmes whether they are multi-company or multi-national. The Space Station can be a prime example of that.

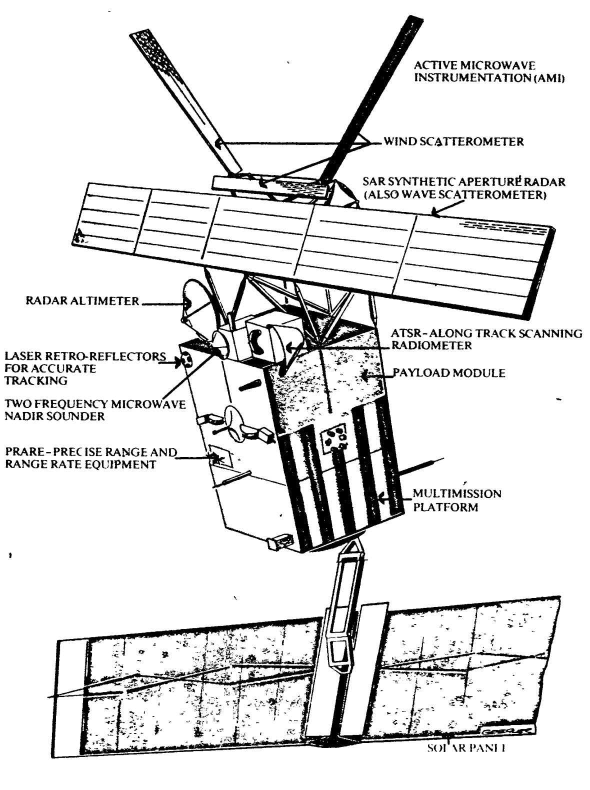
Specifically for the twenty-first century we see:

- Both high and low resolution instrumentation in the five to 60 metre and 500-1000 metre range.
- Flexible instruments that can perform both land and ocean sensing missions.
- Multi-mission payloads that can provide environmental, Earth sensing and various forms of radar data simultaneously.
- World-wide networking of low cost terminals automatically collecting and processing multi-mission data.
- A multi-national data base with integrated environmental, land, and oceans data; with terminal access on a world-wide basis.
- One world-wide scientific council that provides oversight and guidance for space activities.

Remote sensing from space is a world-wide resource and is now moving from its "transition" or "development" stage to practical applications. It is a new industry and about to explode in new applications and usage throughout the world. Over the next 10 to 20 years, better education of the user community will continually spawn new applications and products, and greatly enhance the development of new oil and gas reserves, urban planning and food production.

High quality imagery from the French Spot-1 satellite is shown in this 10 m panchromatic view taken on March 4, 1986 of the Greek town Elevsis, west of Athens. Boats moored in the harbour and details of an airport can be clearly seen. *NPA*

European Remote Sensing Satellite



ERS-1 is expected to be the forerunner of a series of European remote sensing satellites to become operational in the 1990s. It will have three major missions:

Meteorological mission – **concerned mainly with short- and medium-term weather and sea state forecasts requiring near real-time data acquisition and processing.**

Climatological mission – **a long term mission based on continuous monitoring of various oceanic parameters.**

Imaging mission – **to acquire high resolution all-weather SAR (Synthetic Aperture Radar) data to monitor land and sea ice, coastal processes and land surfaces.**

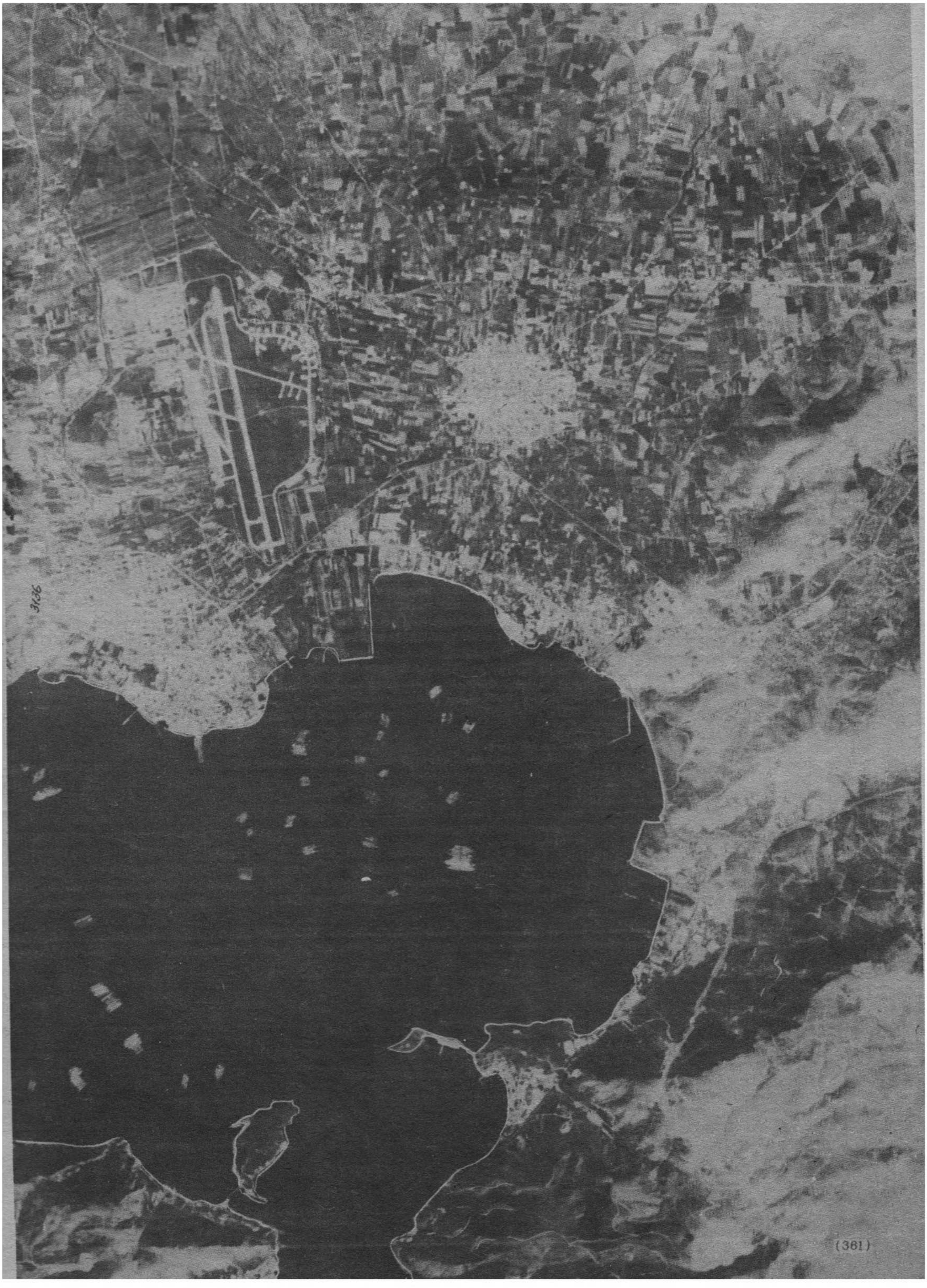
Launch: 1989

Orbital parameters:	**AMI* SAR mode:**
Orbit: circular sun synchronous	**Frequency: 5.3 GHz**
Altitude: 777 km	**Wavelength: C-band**
Inclination: 98.5 degrees	**Resolution: 30 m**
Period: 100 minutes	**Swath: 99 km**
Repeat cycle: 3 days	**Active Microwave Instrument*

UK involvement

The ERS Data Centre at the Royal Aircraft Establishment, Farnborough will be responsible for archiving the data from the ERS satellites, extracting geophysical data and developing analysis techniques and applications.

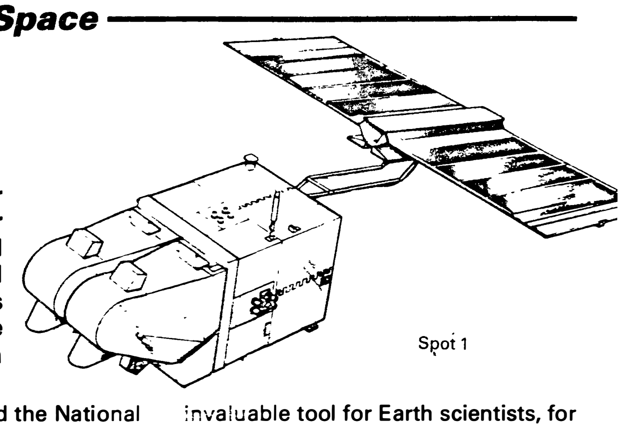
It is planned to launch ERS-2 two or three years after ERS-1, possibly with a sensor to measure ocean colour. Further satellites in the series may be land oriented.


3136
(381)

Spot Data Distribution

by Paul Archer*

The launch of the French Spot satellite in February of this year ushered in a new era for remote sensing, making available for the first time images of the Earth's surface on a commercial basis. Spot Image, rapidly developing an extensive and ambitious distribution programme for its data, already has agents in some 38 countries and is now beginning to reap the rewards for France of an idea first generated more than a decade ago as a potential European collaborative project.



Spot 1

The Spot programme was originally conceived in 1976 as a European Space Agency Project. However, ESA chose not to support the scheme leaving France to continue with its own research and development progamme. In 1981 France committed itself to returning the investment for the Spot programme and attain full commercial viability as early as possible. Spot Image was duly formed in July 1982 as the commercial operator for the programme in asso-ciation with CNES (Centre National d'Etudes Spatiales) which operates the technical facilities of the spacecraft and ground segment.

Spot Image is a private consortium with CNES (39 per cent) as the major shareholder. Other shareholding concerns are also French, although the Swedish Space Corporation (six per cent) and a number of Belgian firms (two per cent) are represented.

Spot Image has set up a world-wide marketing structure which is centred on its computerised catalogue system and which makes use of Spot's unique data acquisition facility. There is currently a distributor network consisting of agents in some 38 countries who are responsible for developing commercial relations with clients and organising data and product distribution on demand.

There are two official distributors in the UK, Nigel Press Associates (NPA), of Edenbridge, Kent, and the National Remote Sensing Centre (NRSC) at Farnborough. Both use direct links to the Spot catalogue system and will coordinate data search requests, programme requests and firm orders on behalf of commercial clients.

Programme Requests provide a facility to programme the satellite on demand by the client and are a novel and unique feature of the Spot system. If a customer requires data within a specified time period (and if imagery of the area is not already held in the archive), then the customer can submit, via the distributor, a request to acquire that data according to specified paramaters such as geographic area, image recording periods, viewing angle and cloud cover constraints. This facility is obviously important for scientists wanting multi-temporal images at regular intervals.

On receipt of the request Spot Image undertakes a technical study to determine the feasibility (ie probability) of the required acquisition during Spot's programme cycle for that period. The customer is then asked to accept or reject the technical conditions of acquisition put to him by Spot Image. If he rejects, he can modify the request to initiate a new feasibility study. If he accepts, he is then obliged to purchase the data subsequently acquired by Spot according to the agreed specifications.

Acquisitions can also be carried out by Spot on an 'Urgent' basis. This too is an important and unique feature which will enable users to request that imagery be acquired within only a few days, cloud permitting. The facility will be an invaluable tool for Earth scientists, for example, involved in monitoring natural disasters such as earthquakes and flooding. Naturally the media will also have access to this high resolution imagery of areas of news value which they would not be able to obtain by other means. Spot Image can programme Spot within three to eight hours of receiving an Urgent Request.

What is Spot doing when it is not acquiring imagery on demand from programme requests? Quite simply, Spot Image intend to generate a base archive of all land areas of the globe. Known as Systematic Surveying, it is carried out with reference to 181 homogeneous climatic zones which enable Spot to acquire imagery during favourable periods of low cloud cover probability.

The facility to select and acquire images on demand should not be underestimated. Spot had, for example, acquired images in its first 30 days of operation of 80 per cent of the world's capital cities. This would not have been possible with previous Earth resource satellites. By July a total of around 50,000 scenes had been acquired, although only some 50 per cent are acceptable in terms of cloud cover and image quality. Of these, about 600 scenes have been processed to CCT (Computer Compatible Tape) and are available to users. Many Programme Requests to obtain imagery on demand are currently being processed by Spot Image.

The computerised catalogue system or BRAMS (Browse and Mail Service) maintains an inventory of all images received and processed worldwide. The catalogue is updated continuously so that distributors have immediate access, via a direct link, to the latest data and product availability for Spot users. The catalogue reports primarily on parameters such as scene location, acquisition mode, viewing angle, scene ID, quality and cloud cover, but more complex data management of library packages will be made available in due course. In some cases users who have frequent need of coverage information can

Paul Archer is marketing and sales manager for Nigel Press Associates, a specialist organisation with over 12 years experience in remote sensing. The company offers production and interpretative facilities using in-house equipment for computer and photographic image processing.

Follow-on Programmes

Spot-1 has an expected life of about two years and, in time, will be replaced by the identical satellite Spot-2. Two further satellites are under development, which will provide continuity of this operational system for more than a decade and will also carry improved and new sensors. Launch dates are anticipated to be as follows: Spot-3 about 1990 and Spot-4 in the period 1994-1998.

On Spot-3 and -4 new CCD (charged-coupled device) arrays will allow an additional 20 m resolution band in the mid infra-red (between 1.5 and 1.7μm), which is of particular importance in vegetation monitoring.

A new instrument will be added to provide regular and global monitoring of vegetation as a primary tool for production assessment. It will record wide-field images (swath width of about 2000 km) with a resolution better than 1 km in each of the four Spot-3 HRV (High Resolution Visible) bands.

Also, the current panchromatic band will be replaced by band 2 operated at 10 m resolution. Then 20 m and 10 m mixed data sets will be offered with built-in geometric registration between all channels.

A multispectral Spot scene taken over eastern England on February 26, 1986. The reddish area in the centre is Thetford forest and the town to the lower right Bury St. Edmonds. *NPA*

obtain a direct link for themselves. This service is free of charge at present.

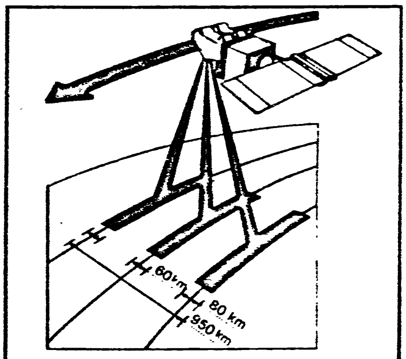
Spot Image has rightly taken a strong commercial stand on the sales and distribution of its data. The latter are protected by a stringent copyright and royalty agreement with the purchaser. In early days Earth resource satellite data were freely copied and transferred or swapped between users. This is now illegal for Spot data and transgressors will be actively sought out by Spot's legal department.

The onward sale or transfer of data and products by a purchaser to a third party is of course subject to the copyright regulation. In these cases the purchaser is required to pay a royalty fee for any subsequent transfer of materials. The implications of the strict copyright conditions and royalties indicate that Spot Image is in reality 'licencing' the use of data, rather than actually 'selling' it.

Spot digital CCT's are available at around £1000. For this the user obtains either three bands of 20m resolution multispectral data or one band of 10m resolution panchromatic data. A Spot stereo pair is considered to be two separate scenes and is charged accordingly. If a scene has been processed and is held in archive, the user may order photographic material at around £500 for film negative or positive and around £350 for a 1:100,000 scale print.

Spot Image believes that satellite remote sensing will only become commercially viable with users accepting the full commercial costs of the data. The key problem is to dramatically expand the market for data and products by demonstrating to new users the benefits of using Spot data and products. Spot Image and its distributors are actively involved in this task, secure in the knowledge that the scientific community now has a remote sensing system able to deliver high quality imagery on a timely and efficient production basis.

Part of the marketing programme during the coming months involves more than 130 studies on Spot data which will be carried out around the globe to evaluate its quality and suitability in specific applications areas.



Off nadir-viewing

It is possible to steer the mirrors of the HRV (High Resolution Visible) instruments to view obliquely (off nadir) up to 27 degrees either side of vertical to cover an area of interest within a 950 km wide strip centred on the satellite ground track.

The width of the observed swath varies between 60 km for nadir viewing and 80 km for extreme off nadir-viewing.

Spot Scenes

Each Spot scene is recorded in one of two possible modes: panchromatic (PA) or multi-spectral (XS). For instrument viewing directions close to the vertical, each scene covers an area of 60 x 60 km. In contrast, scenes recorded at the extreme oblique viewing angles (27 degrees) cover an area of 60 x 80 km.

In the panchromatic mode, the number of pixels per line is between 6000 and 10,400 and lines per scene vary from 6000 to 9000 depending on angle of view and the preprocessing level. The volume of data per scene varies from 32 to 100 Mbytes.

In the multi-spectral mode, the number of pixels per line varies between 3000 and 5200, while the number of lines per scene ranges from 3000 to 4900 for each of the three spectral bands. The total volume of an XS scene ranges from 27 to 76.5 Mbytes.

British Association of Remote Sensing Companies (BARSC)

With the launch of many new Earth observation satellites over the next decade, British companies involved in remote sensing are optimistic that the range of practical applications of space imagery will grow rapidly. It is against this exciting background of development and commercial opportunity that the British Association of Remote Sensing Companies has been formed.

The objectives of BARSC are to promote cooperation between all UK companies and partnerships offering consulting and contracting services in the field of remote sensing, to liaise with government departments and academic institutions and to encourage international agencies or organisations undertaking remote-sensing projects overseas to cooperate with BARSC and its members.

For further information contact: Mr. C. Aidan Connolly (Secretary) Lansing Bagnall Bldg., Edenbridge, Kent, TN8 6HS. Tel. (0732) 865023.

Stereoscopic Viewing

The main applications for stereoscopic imagery are in photogrammetry for cartographic purposes and photo-interpretation for geological, geomorphological and hydrological studies. The following will be possible:

- Compiling topographic maps with uniform vertical contour interval of 20 to 50m.
- Perception of large man-made structures and gross vegetation features.
- Direct compilation of digital terrain modes.

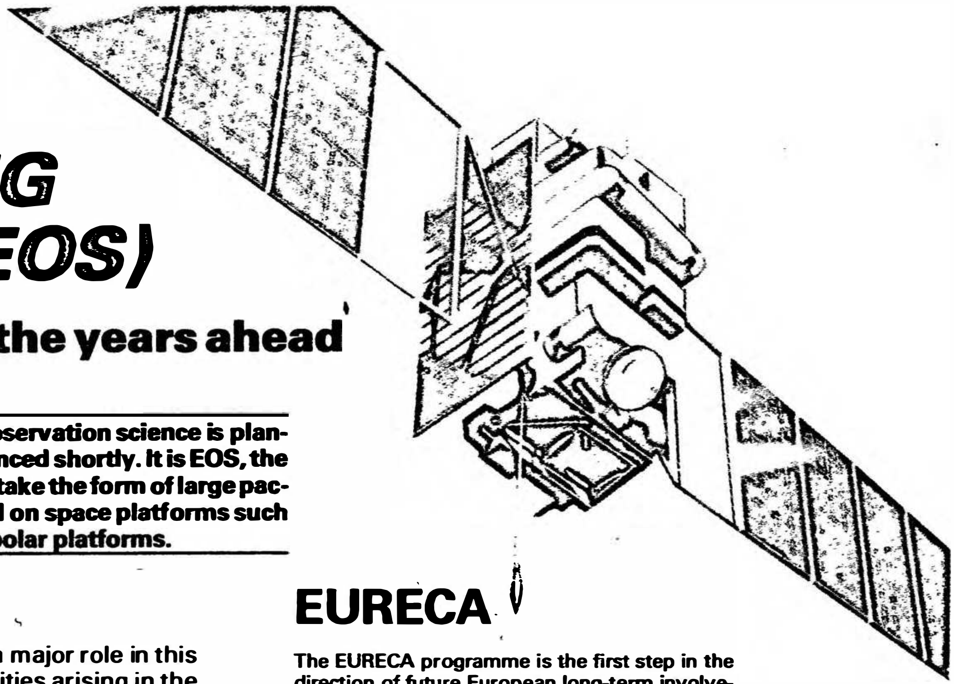
Images recorded on successive days are acquired on either side of the vertical. In such cases the ratio between the observation base (or distance between the two positions of the satellite) and the height (or satellite altitude) is approximately 0.75 at the equator and 0.5 at a latitude of 45 degrees permitting stereo viewing.

Compared with stereopairs obtained from aerial photographs, the main features of Spot stereo images are:

Scene size: large format size – 60 x 60 km compared with 5 x 5 km or 10 x 10 km.
Scales: from 1:400,000 to 1:25,000.
Projection: Spot stereo imagery is a cylindroconic projection. However, they can be used in virtually the same way as conic projection air photos. Special attention is required to maintain the observation base under the stereoscope perpendicular to the satellite ground track and to ensure that the viewing axis remains as close as possible to the vertical.
Homogeneity: as is the case with all images of the Earth recorded by satellites, Spot imagery is quite remarkable as regards the uniformity of projection and the conditions of observations.

EARTH OBSERVING SYSTEM (EOS)

– looking down in the years ahead



A major new opportunity in Earth observation science is planned by NASA and is due to be announced shortly. It is EOS, the Earth Observing System, which will take the form of large packages of instruments to be mounted on space platforms such as the Space Station or associated polar platforms.

EURECA

The EURECA programme is the first step in the direction of future European long-term involvement in space transportation systems providing experience in the development of unmanned, automated platforms.

EURECA will be launched from the Space Shuttle. After deployment from the Orbiter, the platform's own propulsion system will take it into its operational orbit with an inclination of 28.5 degrees some 525 km from Earth. Its large solar arrays will then be deployed and its thermal/cooling and data systems switched on and tested. Finally, the payload will be switched on and operated by remote control from an ESA ground station under the responsibility of the European Space Operations Centre (ESOC).

On completion of its mission six to nine months later, the platform will return under its own power to meet the Shuttle in an orbit 296 km from Earth. The Orbiter's remote manipulator arm will retrieve the platform and place it in the cargo bay, ready for its return to Earth.

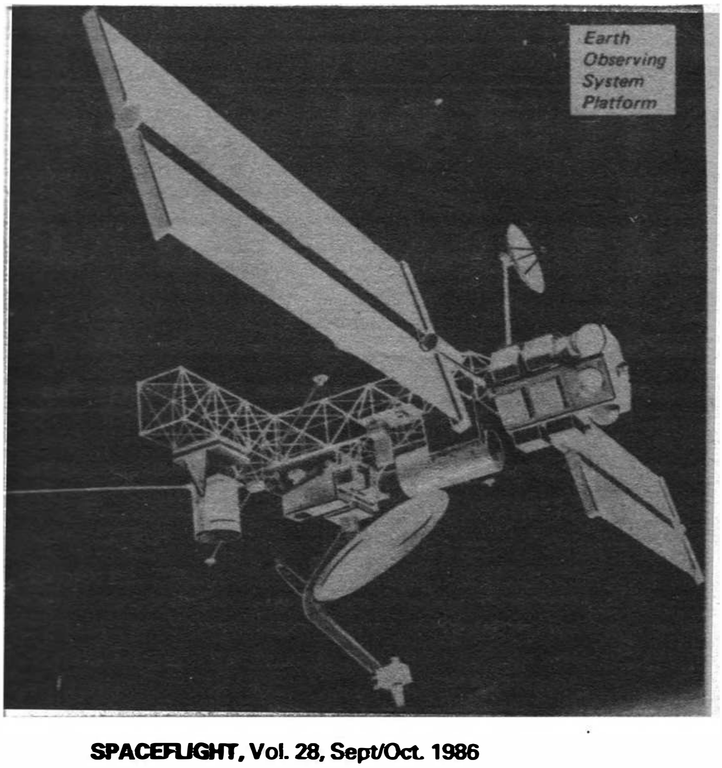
UK involvement

UK scientists are expected to play a major role in this area of science with further opportunities arising in the European Space Agency's unmanned EURECA (EUropean REtrievable CArrier) programme. EURECA is to be launched and retrieved by the Space Shuttle after a typical mission of six to nine months in a 525 km orbit to which it will be self-propelled from Shuttle orbit altitude.

New payloads would be fitted and flown every 18-24 months. EURECA has aroused considerable interest in Europe and elsewhere, both in its own right as an experiment carrier and also as a bridge to future use of the Space Station.

An important element of the Space Station is the European Columbus project with much UK interest centred on the inclusion of an unpressurised polar-orbiting platform, this being ideal for Earth observation on account of its polar orbit.

The extent of future UK participation in the Columbus project is to be announced shortly as part of Britain's first National Space Plan. Speaking at a British Interplanetary Society Space Station Symposium in London recently (see *Spaceflight*, July/August 1986 p. 295), the Director-General of the British National Space Centre, Mr. Roy Gibson, said that a 15 per cent UK contribution to the whole Columbus project was envisaged and that the UK would be looking for prime contractorship of the polar platform being prepared to allocate 60 per cent of its budget to this item.



21st Century

Beyond year 2000, Earth observation can be expected to benefit from the existence of a Space Station complex, a polar-orbiting platform and relatively cheap access to these facilities. Technical trends will be towards large aperture radiometers and spectrometers of 10-20 metres dimension at microwave and sub-millimetre wavelengths and of 1 m dimension at infrared wavelengths and towards large aperture visible array imaging and Doppler resolving spectrometry capabilities.

Active in this field of research are scientists of the Atmospheric Sciences Division of the Systems Dynamics Laboratory of NASA's Marshall Space Flight Center which is preparing high resolution microwave radiometers for measuring tropical rainfall amounts.

Details of the Earth's water cycle and global rainfall are poorly understood. In particular, tropical rain patterns through their release of latent heat help to drive the atmosphere and affect the weather on a global scale. The Global Precipitation Observation System being developed by the Marshall Center will be a key element of EOS for use on the manned Space Station and on unmanned polar platforms in the 1990's and beyond.

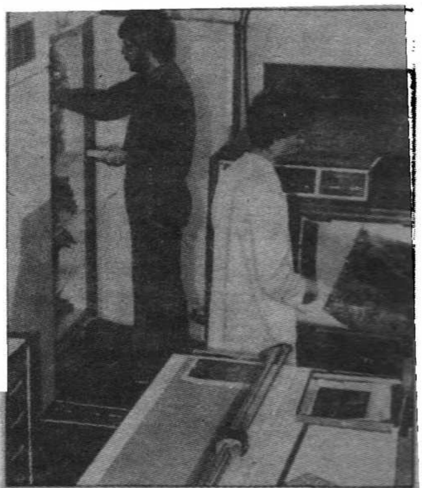
Facilities and Services

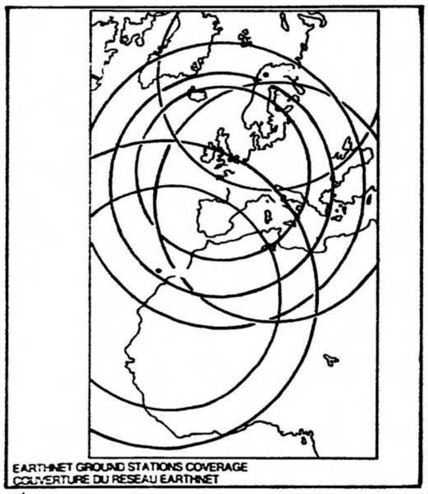
Digitally processed NOAA image of sea surface temperatures in the N.E. Atlantic.

The major roles of the National Remote Sensing Centre (NRSC) include the introduction of new users to satellite imagery, the demonstration of how data can bé used for a variety of applications and the provision of facilities and services for any user of remote sensing data.

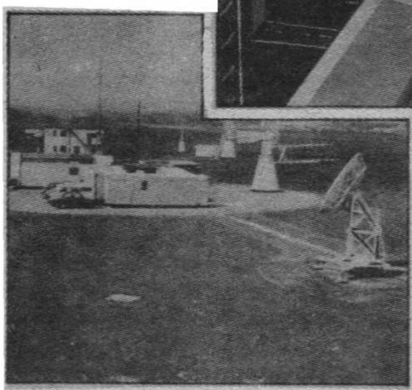
Services provided are for the reception, processing and distribution of data from NOAA Meteosat and GOES Meteorological satellites. Data are received at the ground station at RAE Lasham, in Hampshire for the British Meteorological Office and other users requiring data for weather forecasting and oceanography, as illustrated by the picture on the right.

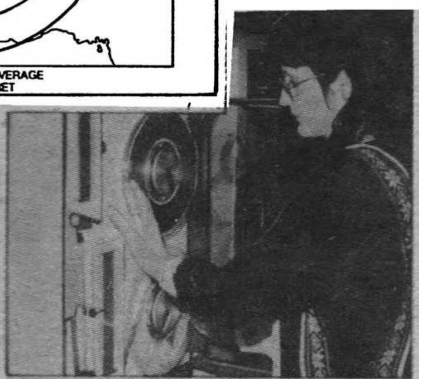
The main areas of NRSC are listed on the right and individually illustrated here.





- **Image processing**
- **Applications**
- **Mobile exhibition**
- **Metsat services**
- **User services**
- **Photographic products**
- **Interactive image analysis**
- **Digital products**





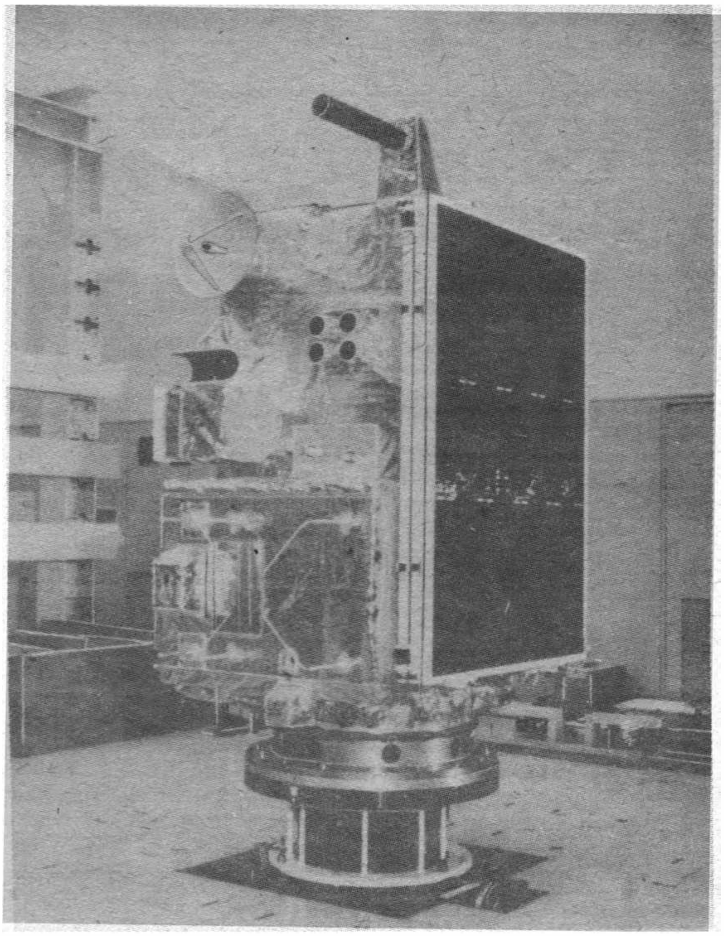
Japan Invests in Earth Observation

The Remote Sensing Technology Center of Japan (RESTEC) was established on 28 July 1975 to spearhead Japan's research and development into remote sensing and its application to economic development, social welfare and environmental protection.

In January 1979, the Earth Observation Centre, National Development Agency of Japan (NASDA) commenced operations and Japan was able to receive Landsat-2 and -3 data directly from these satellites. Also, work commenced on Marine Observation Satellite-1 (MOS-1) which was due to be launched in August of 1986. Since 1979, RESTEC has become more and more important, undertaking data distribution inside and outside of Japan and the analysis of Earth observation data.

In March 1978, Japan's Space Activities Commission formulated Japan's space development policy for the next 15 years. Earth observation, including meteorology, will provide the main framework for Japan's space development as well as the field of telecommunications and broadcasting.

MOS-1 (right) was due to be launched into a sun-synchronous orbit before the end of the summer using the N-II vehicle in order to observe marine phenomena and to establish fundamental technologies for Earth observation satellites. There are three onboard sensors, a multi-spectrum electronic self-scanning radiometer (MSSR), a visible and thermal infrared radiometer (VTIR), and a microwave scanning radiometer (MSR) Its mission life is two years and the prime contractor is NEC Corporation. *NASDA*



REMOTE SENSING OF SUSPENDED SEDIMENTS IN COASTAL WATERS

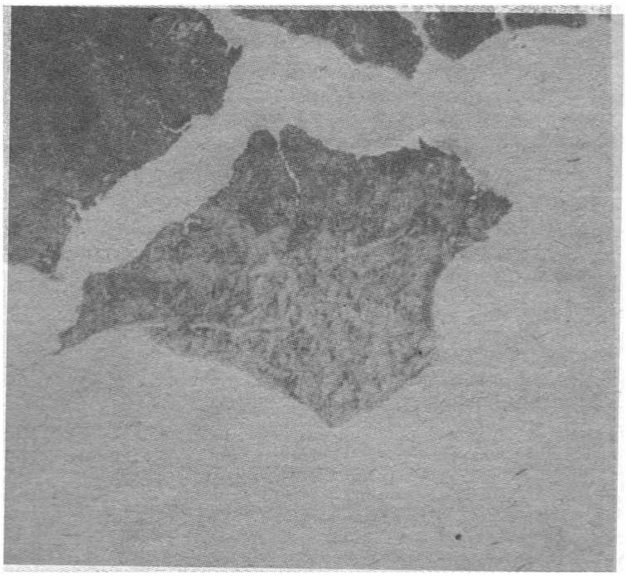


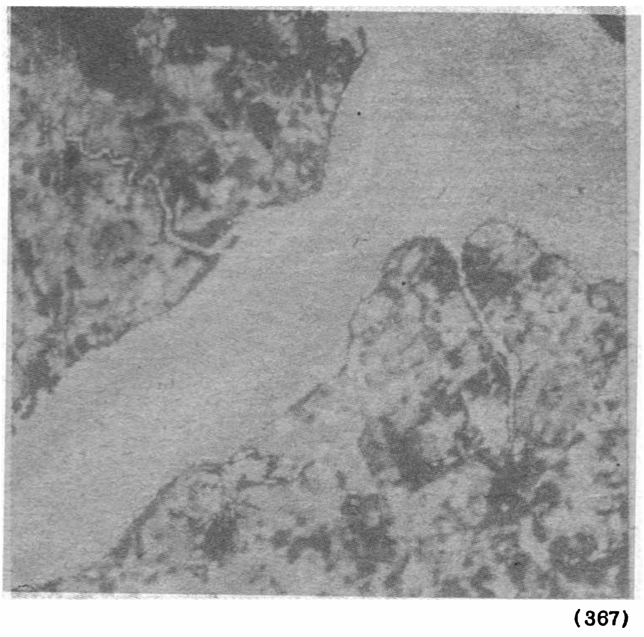
Fig. 1 Landsat 2 Multi Spectral Scanner provides a false colour composite, showing the Solent estuary and coastal waters around the Isle of Wight on the south coast of England.

Satellite-mounted scanning radiometers measuring visible-wavelength light generate images of sea colour which describe the distribution of suspended sediment material in the near-surface layers of the sea.

The resolution of 80 m achieved with Landsat provides sufficient detail to study large estuarine regions such as the Solent on the south coast of England (Fig. 1) where suspended sediment shows up in white.

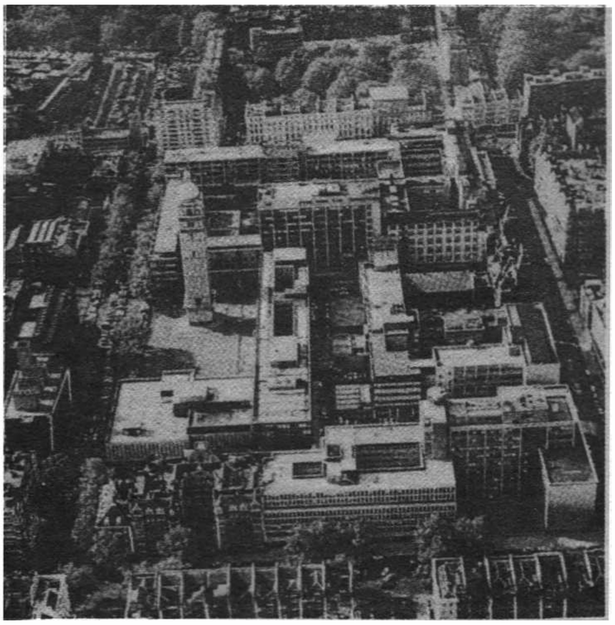
A colour slice enhancement of a single Landsat MSS band (Fig. 2) not only shows up the suspended sediment distribution patterns, but is capable of quantitative calibration as a map of suspended sediment concentration.

Fig 2. Colour slice enhancement of Landsat 2 MSS band 5.



Centre for Remote Sensing – offers teaching and research

Situated in London at the Imperial College of Science and Technology, CRS is a major national and international facility, where teaching and research are providing a firm foundation for the future expansion of Remote Sensing. The Centre is designed to exploit the many links between College, government and industry with activities in Earth resources, vegetation studies, geology, oceanography, atmospheric physics, medical physics, image processing and pattern recognition.



The Imperial College of Science and Technology at Kensington, London, and the location of the Centre for Remote Sensing.

CRS Work in Geology

Projects include interpretations of aerial photographs and Landsat imagery for geological mapping in mineral exploration, engineering and tectonic hazard monitoring. Study areas include Ireland, SW England, the Pyrite Belt of Portugal-Spain, Southern Africa and Mozambique.

Other research topics under development include studies of gold and other minerals, exploration in southwestern USA using thematic mapper data from Landsat 4, engineering geology mapping in Brazil, together with assessment of the uses of radar and thermal imagery for mineral exploration in glaciated terrain. Planetary geological studies are being conducted for Mars using Viking data and of the satellites of Jupiter and Saturn using Voyager observations in order to extend our understanding of geological processes.

Geological study areas include SW England.

Teaching

The first MSc degree course in Remote Sensing in the UK is organised by Imperial College through members of the Centre for Remote Sensing in conjunction with University College London. The 12 month course of lectures, practical image processing studies using the Centre's facilities and a dessertation study comprise the structure of the MSc course.

Further advanced lecture courses and practicals in remote sensing are concerned with more specialised areas of study, such as MSc degree courses in Atmospheric Physics and Dynamics, Mineral Exploration, Environmental Technology and Petroleum Exploration.

Further information from: The Chairman, Centre for Remote Sensing, Imperial College of Science and Technology, The Blackett Laboratory, Prince Consort Road, London SW7 2BZ.

Hertfordshire from Space

A view of "Hertfordshire from Space" has been produced by Hunting Surveys and Consultants in association with Herts County Planning Department from Landsat satellite data for use by local schools and residents.

The main features of Hertfordshire towns and countryside are clearly visible on the poster-sized view, which shows the route of the M25 motorway and the complex patterns of agriculture, woodlands and buildings across the county. Schools will be taking a fresh look at the way that the county is developing and appreciate the benefits offered by satellite images.

Copies of the view can be seen in all Herts libraries and are on sale from the Country Planning Department, County Hall, Hertford.

Spaceflight

NOVEMBER 1986 £1.25

The International Magazine of Space and Astronautics

CONTENTS

Editor:
G. V. Groves

Assistant Editor:
C. A. Simpson

Managing Editor:
L. J. Carter

Spaceflight Sales:
Shirley A. Jones

Advertising:
C. A. Simpson

Spaceflight Office:
27/29 South Lambeth Road,
London. SW8 1SZ. England.
Tel: 01-735 3160.

DISTRIBUTION DETAILS

Spaceflight is available world-wide by annual subscription. The rate for 1986 (10 issues) is £30.00 (US$50.00) inclusive of surface mail delivery. Subscribers also receive the publication *Space Education* (two issues) at no extra charge

Back issues of ***Spaceflight*** are supplied from available stocks at £2.00 (US$4.00) each, inclusive of surface mail delivery.

Spaceflight may also be received regularly by mail through membership of the British Interplanetary Society. Details of application are available from the Executive Secretary.

* * *

Spaceflight is distributed in the UK through newsagents by Profile Books Ltd., 1 Pontiac Works, Fernbank Road, Ascot, Berks SL5 8JH. Telephone 0344-884222. (If you have difficulty in obtaining your copy of ***Spaceflight*** please notify Profile Books, Circulation Manager (at Ascot) in writing, stating the name and address of the newsagent).

* * *

Published by the British Interplanetary Society Ltd., (No. 402498). Registered office: 27/29 South Lambeth Road, London, SW8 1SZ, England.

Vol. 28 No. 11 November 1986

В журнале не печатается ряд страниц.

Front Cover: An impressive view of the Soviet 'Proton' three-stage liquid-fuel launch vehicle which has been used extensively since 1965. Payloads that have been put in orbit with it include the Mir space station (p.384) and the Vega (Venus lander/fly-by and Halley Comet fly-by) probes (p.386). In 1983, Proton, which is capable of a direct launch to geostationary orbit, was offered commercially in competition with the Shuttle, Ariane and other western launch vehicles, but so far the offer has not been taken up.

T 2.

UK Soviet Space Deal

Recently improved East-West relations now offer the prospect of joint UK-Soviet space missions. The Soviet offer made earlier this year to fly a British cosmonaut is being kept 'on hold' by the British National Space Centre (BNSC) while arrangements are worked out for a collaborative space science programme in astronomy and geophysics.

Space Science Priority

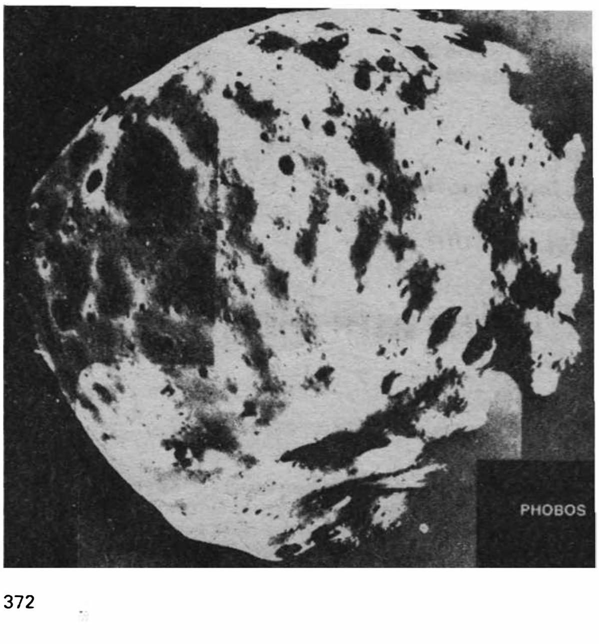
UK interest in space science has been long-standing and at the forefront of international achievement. Instrumentation prepared mainly in UK university departments has traditionally reached orbit through the ESA space science programme or collaborative NASA programmes. Future launch schedules now stand severely disrupted by the postponement of Shuttle launches and recent failures of US and European launch vehicles. In contrast, Soviet launchings have continued unabated with the flexibility to offer spare payload capacity at relatively short notice.

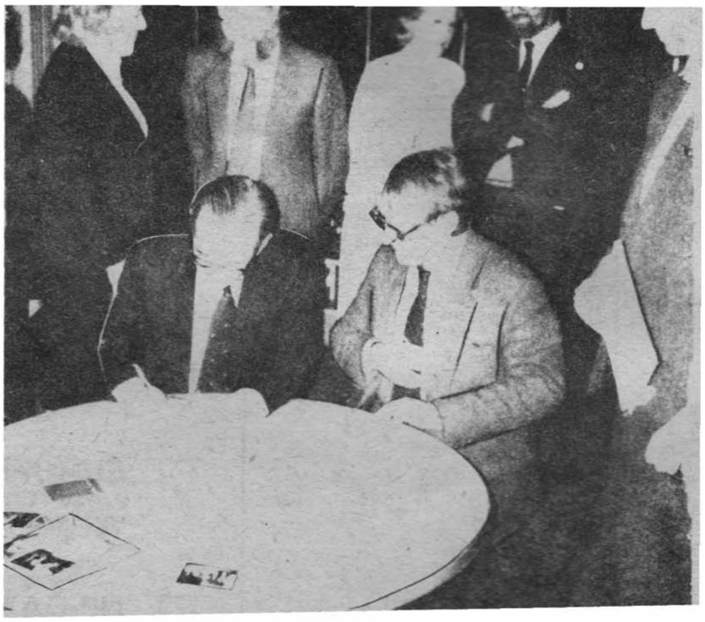
Soviet Institute of Space Science

Ahead of the announcement of an initial UK/Soviet space agreement, working level exchanges have been underway between UK scientists and their opposite numbers at the Soviet Institute of Space Science.

This Soviet Institute has previously played a leading role in East-West collaborative space projects, notably in the Vega Project to Halley's Comet with instrumentation developed jointly by Austria, Bulgaria, Czechoslovakia, France, Hungary, GDR, FRG, Poland and the USSR.

Academician R. Sagdeyev, a leading member of the Institute reports on the results of the Vega project specially for ***Spaceflight*** readers on p.386 of this issue. It has been at his invitation that a UK delegation of space scientists, led by Roy Gibson, Director General of BNSC, visited the Institute from 29 September to 1 October 1986 to discuss seven possible areas of UK/Soviet collaboration that had been suggested by the Soviets.





Mr Roy Gibson for the UK and Academician R Sagdeyev for the USSR sign an initial agreement on co-operative space missions at the end of discussions held in Moscow between 29 September and 1 October 1986. A formal Memorandum of Understanding on space collaboration is due to be signed in the coming months after further details have been satisfactorily worked out

Phobos Investigation

Phobos, the inner satellite of Mars, is the prime target of the Mars-Phobos spacecraft to be launched by a Proton booster in July 1988. On approaching Phobos two landers will be deployed from the main spacecraft which will then remain in the close proximity of Phobos to undertake a detailed surface examination at distances down to 50 metres. This phase of the mission will last for 140 days and will be fully televised.

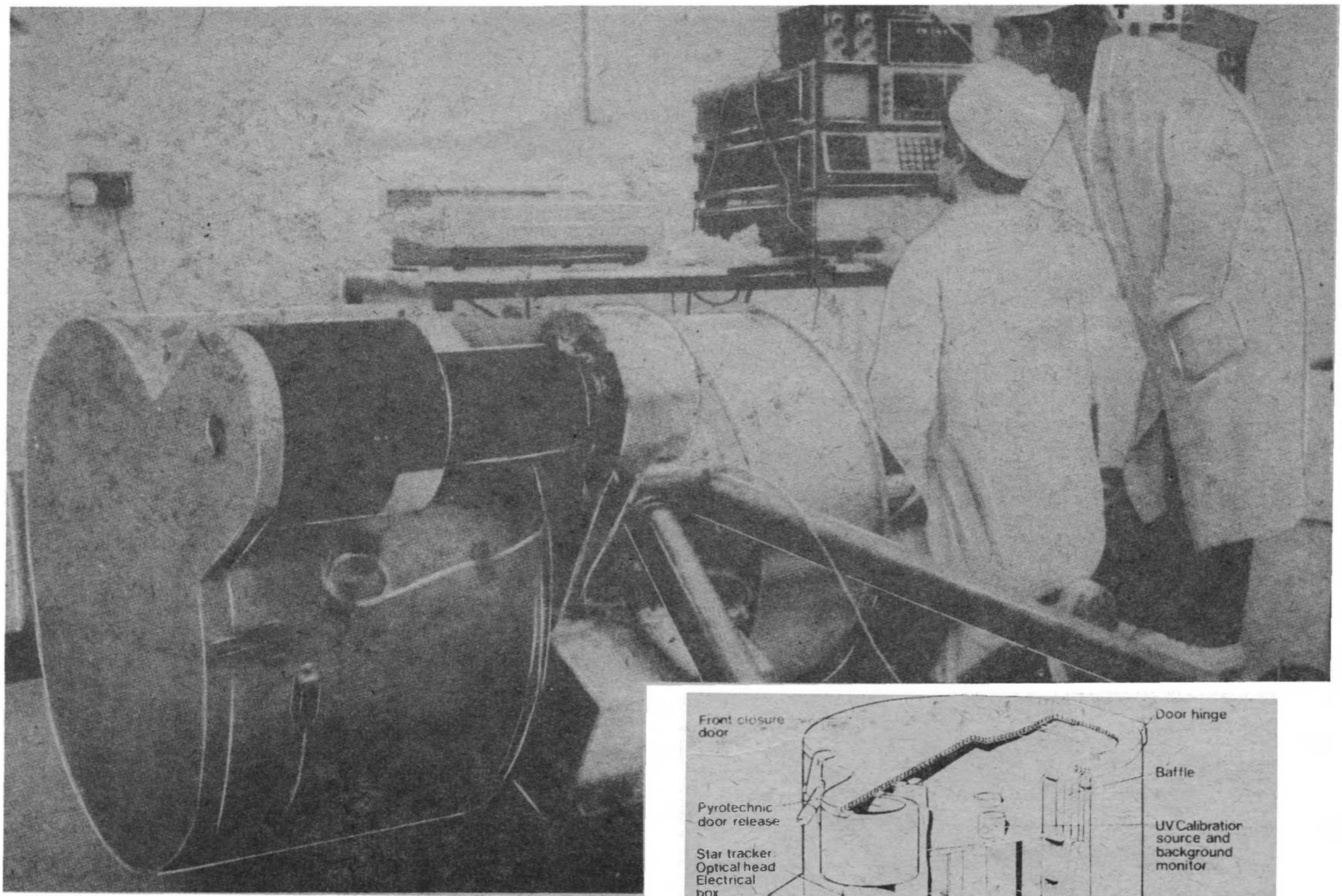
Under the UK/Soviet space agreement UK scientists will participate in the Phobos surface investigation and will be actively involved in the interpretation of data during the 140 day observing phase. Details of the Phobos mission and its principal experiments have previously been reported in ***Spaceflight*** (March 1986, p.113).

X-ray Astronomy Highlighted

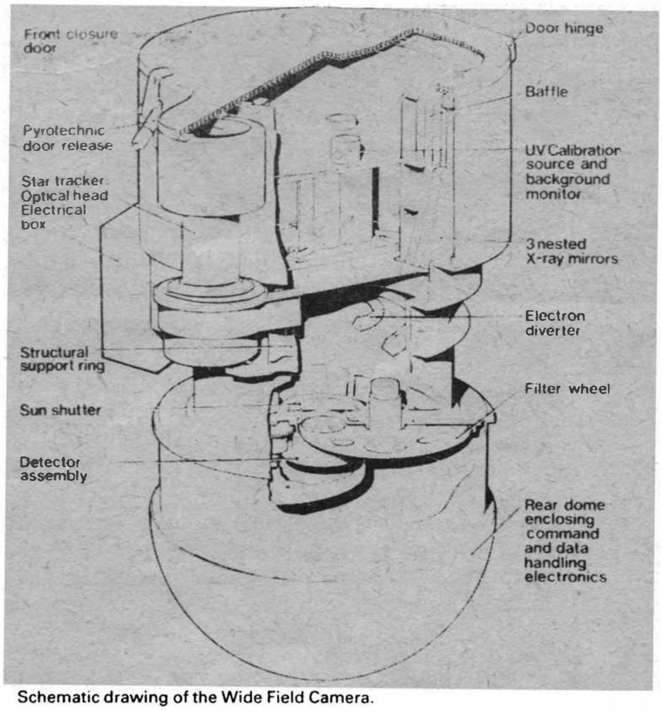
UK contributions to X-ray astronomy are expected to provide a basis for long-term UK/Soviet collaboration and the Soviets are considering possible offers of payload space to UK scientists. On the UK side the project will be led by the University of Birmingham.

Solar X-ray instrumentation has previously been developed jointly by the University of Birmingham and the Space Research Institute in Utrecht, Holland. These laboratories combined their resources at the time of the last solar maximum to design and construct a hard X-ray imaging spectrometer for NASA's Solar Maximum Mission (SMM) spacecraft which was launched by a Delta rocket on 14 February 1980 from Cape Canaveral, Florida.

Since 1981, the laboratories at Birmingham and Utrecht have been collaborating with the Institute for Cosmic Research, Moscow in the development of an X-ray astronomy telescope to be mounted with other X-ray astronomy instrumentation on a Soviet space station where periodic monitoring and servicing by visiting cosmonauts would insure against a sustained failure of the equipment as happened with the SMM spacecraft in 1980 when the attitude control system failed. Launch plans provide active operation for up to 5 years.



The structural thermal model of the Wide Field Camera undergoing model survey testing in the Birmingham University clean room



Schematic drawing of the Wide Field Camera.

Cosmic XUV Astronomy

Another UK development in space astronomy that is well advanced is the so-called Wide Field Camera (WFC) with which it is planned to make the first all-sky survey at XUV wavelengths from 60 to 300 Angstroms. The camera has a 5° field of view with a spatial resolution of 1-2 arc minutes. Its pointing accuracy is that of the space platform to which it is attached.

The instrument was originally scheduled for a Shuttle launch in 1988 as a component of the ROSAT Project to survey the complete sky at X-ray wavelengths. A delay of many years is now inevitable if the project remains linked to the Shuttle programme.

The possibility of a launch on a Soviet vehicle is currently being pursued and operational requirements for data collection are under discussion.

The WFC has been developed by a consortium of UK research groups consisting of the Rutherford Appleton Laboratory, University of Leicester, Mullard Space Science Laboratory – University College London, University of Birmingham and the Imperial College of Science and Technology.

Further Projects

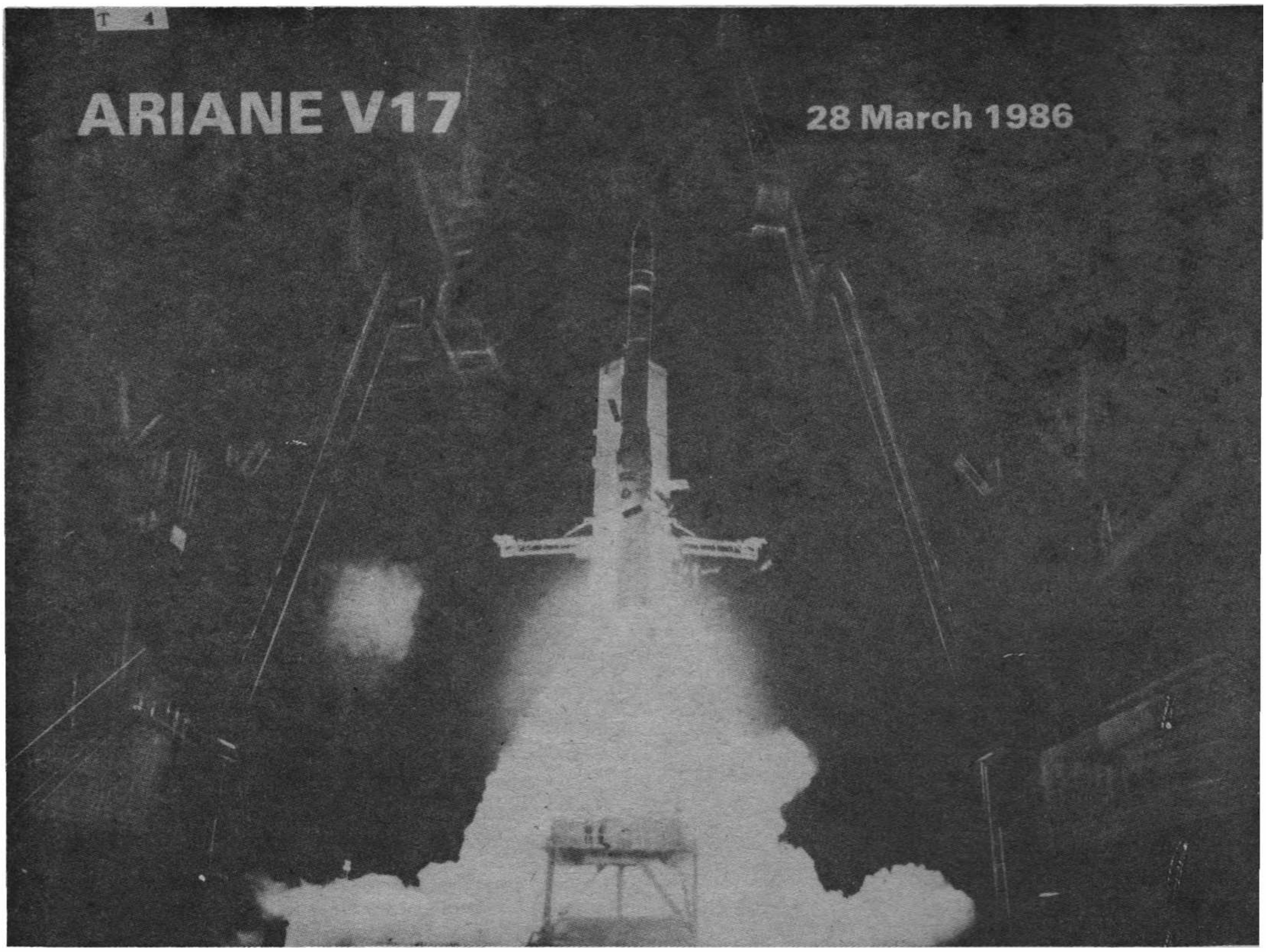
The Soviets have also proposed collaboration in sub-millimetre astronomy, the life sciences and the material sciences. Their interest in the life sciences is in areas of clinical research in Britain which could assist their long-endurance manned flights, such as work on muscle degeneration. Joint work in the material sciences would involve experiments to go in furnaces that are available at the Mir space station or being planned for installation in the near future.

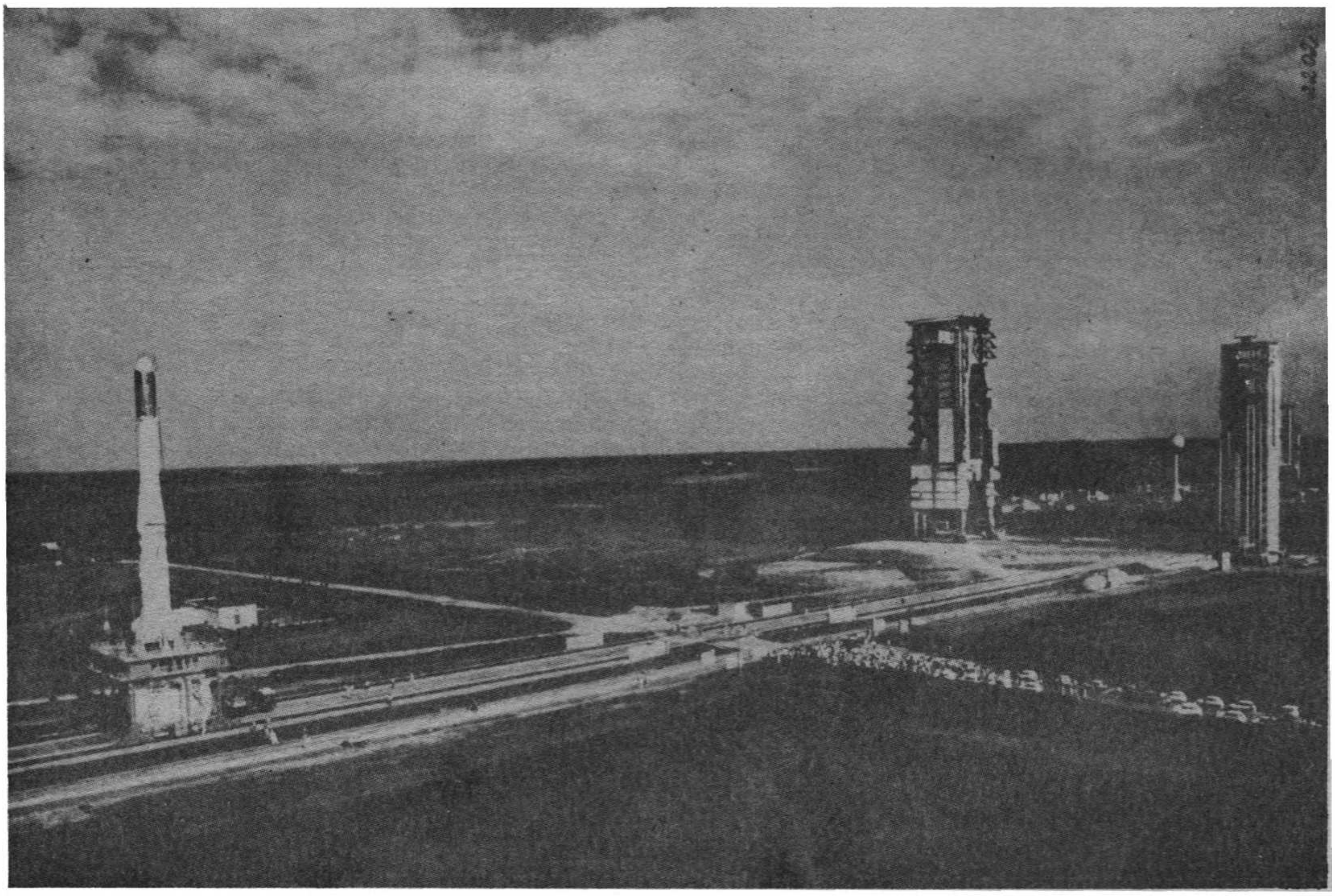
The research capabilities of Mir are to be expanded shortly by the launch and attachment to it of a large scientific module (***Spaceflight,*** Sept/Oct 1986, p.345 and this issue p.384), which will then be available for international collaborative projects.

Soviet space station operations will be increasingly automated in the coming years bringing about a change in the role of a cosmonaut from that of an operator to that of an operations manager overseeing a great diversity of station activities.

The initial UK/Soviet agreement makes no provision for a British cosmonaut payload specialist and official UK sources consider such an arrangement to be a long way off, if ever it should come about.

The arrangements that are in hand for joint space science missions are to be welcomed as they will facilitate interchanges of information and staff and could lead to further joint projects including joint manned missions in the years ahead.


ARIANE V17
28 March 1986



EUROPEAN RENDEZVOUS

ENGINE TESTS UNDER WAY

Flight of the next Ariane rocket has been targeted for February 1987 according to the latest Ariane Launch Manifest released this autumn and reproduced opposite.

The manifest details 23 launches of the Ariane 2, 3 and 4 versions of the European developed rocket now operated commercially by Arianespace

Resumption of flights next February is expected to be confirmed this month (November) following completion of the first part of ignition tests performed on the third stage engine under altitude simulation conditions.

The last successful launch was on March 28 this year when an Ariane 3 placed United States and Brasilian communications satellites into orbit. Subsequently, an Ariane 2 version of the launcher and its Intelsat V 'F14 payload were lost four minutes and 36 seconds after lift-off on May 30 when the third stage engine and start-up phase ceased abruptly.

Arianespace, which held 50 per cent of the world commercial launch market in 1985, has now signed a total of 55 firm launch contracts and has 20 further launch reservations. Of the 55 contracts 38 satellites remain to be launched.

ARIANE LAUNCH MANIFEST

Flight	Month	Vehicle	Payload
			1987
V19	Feb	AR3	ECS4 + AUSSAT K3 (or G STAR III)
V20	Apr	AR2	TV SAT 1
V21	Jun	AR4	APEX 401 (METEOSAT P2 + MAR + PANAMSAT
V22	Jul	AR3	G STAR III (or AUSSAT K3) + SBS 5
V23	Aug	AR2	INTELSAT VF13
V24	Sep	AR3	(TC1 C + SPACENET F3R) or TDF 1
V25	Nov	AR2	TDF 1 or (TC 1 C + SPACENET F3R)
			1988
V26	Jan	AR3	ECS 5 + INSAT 1C
V27	Feb	AR4	ASTRA 1 + MOP 1
V28	Mar	AR2	INTELSAT V F15
V29	May	AR4	SKYNET 4B + TELE X or JC SAT 1
V30	Jun	AR2 or 3	TELE X or OLYMPUS
V31	Jul	AR4	DFS-KOPERNIKUS 1 + JC SAT 1 or HIPPARCOS
V32	Oct	AR2 or 3	OLYMPUS or SPOT 2*
V33	Nov	AR4	SUPERBIRD 1A + HIPPARACOS or INMARSAT II F1
			1989
V35	Mar	AR4	SBS 6** + INMARSAT II F1 or DFS-KOPERNIKUS 2
V36	Apr	AR4	(DFS-KOPERNIKUS 2 + TDF-2) or SPOT 2*
V37	May	AR4	SUPERBIRD iB + GECSTAR or INMARSAT II F2
V38	Jun	AR4	INTELSAT VI F2
V39	Jul	AR4	EUTELSAT IIA + MOP2
V40	Sep	AR4	RCA-K3 + INMARSAT II F2 or SKYNET 4C
V41	Oct	AR4	TrDF-2 or TV SAT 2 + SLUMET 4C or ASC-2
V42	Nov	AR4	INTELSAT VI F3
			1990
V43	Jan	AR4	EUTELSAT IIB + TV-SAT 2 or ASC-2

* SPOT 2 has a contractual priority for launch in case of problem on SPOT 1
** 2nd Right of Refusal for HC1.

CAN ESA AFFORD HERMES?

Hard economics could rule out the French proposed Hermes mini-shuttle from final acceptance as a full-scale European Space Agency (ESA) project after completion of the preparatory study phase now under way.

Speaking at the British Interplanetary Society's Space '86 conference at the end of September, Mr. Roy Gibson, Director-General of the BNSC, said Hermes, which would fly atop the Ariane 5 launcher, was a "very interesting" project.

But he described it as an "optional extra" on Ariane 5. "The question is whether we have enough money to indulge in this little programmatic abberation or whether we should reserve our money to go for the longer term," he said.

Mr. Gibson, the first Director-General of ESA, likened the UK's Hotol spaceplane proposal to "an Ariane 6" and said the space industry needed to see a "substantial reduction" in the cost to orbit in coming years and Hotol was one possible means of achieving this.

Earlier in his presentation Mr. Gibson had spoken of the need to be realistic when formulating budgets to request government funding for space projects.

Governments must be given the full financial facts. Nothing could be worse for European space than to hide the real cost of these programmes, he said.

Launch of an Ariane 3 (above left) on mission V17 carrying the G-star 2 and Brasilsat S2 satellites, and (below) prior to the March 28 lift-off the stack is rolled out to the new ELA-2 launch pad in French Guiana. The next mission, scheduled for February 1987, will also use an Ariane 3 version of the European rocket. *Arianespace*

FINLAND TO JOIN ESA

Finland is to become an associate member of the European Space Agency (ESA), participating in the Science Programme and the Earth Observation Preparatory Programme.

Agreements signed on September 19 by Professor Reimar Lust, Director-General of ESA, and representatives of the Finnish Government oblige the Scandanavian country to give priority to the use of European space transportation systems, facilities and products developed by ESA or its members.

Finland's annual contribution to ESA's general budget will be 50 per cent of the level paid by full member states.

As well as associate membership, Finland will participate in the ESA Science Programme and will have access to observation time and experimental data generated by scientific projects already operating

Finland will also contribute 1.62 per cent to the Earth Observation Preparatory Programme (EOPP) budget, a five year project designed to meet Europe's future needs in the fields of polar observation, a second generation Meteosat and Solid Earth programmes.

Finland, which already participates in the Meteosat Operational Programmes, has indicated its intention to join other ESA programmes and subsequently become a full member of the Agency.

The associate membership and participation in the ESA Science Programme agreements are due to become effective on January 1, 1987. Participation in EOPP was effective from September 19.

EUROPEAN RENDEZVOUS

HOTOL COMPONENT TESTS BEGIN

Rig testing of critical components of Rolls-Royce's revolutionary aerospace engine for Hotol has begun. The tests are steps in a two-year, proof-of-concept study to demonstrate that the combined airbreathing and rocket propulsion engine will work.

They are being carried out by a small team of specialists at the Rolls-Royce plant in Ansty, near Coventry, UK. As development proceeds, critical propulsion system components will be tested on rigs in as near realistic space conditions as can be produced.

The breadth of project design studies, being undertaken at Bristol, is also increasing. The engine concept that is being studied is designated the RB545.

The work relates to the proposed propulsion system for British Aerospace's Hotol spaceplane, which will take off and land like a normal airliner.

The RB545, classified "Secret", uses atmospheric oxygen in the same way as an airliner's jet engines until about nine minutes after launch. Then the engine switches over to use Hotol's on-board liquid oxygen supply to provide the rocket propulsion needed to put the spaceplane into orbit.

Hotol is being designed to put satellites into low-Earth orbit at about one-fifth of the cost of a Shuttle launch by the end of the century. The present phase of work is being funded jointly by Rolls-Royce and the Department of Trade and Industry.

Stewart Miller, Rolls-Royce's Director of Corporate Engineering, said: "The engine concept is unique but we have to answer some major technical questions before we can satisfy ourselves that it will work.

"Our aim during the two-year study we have undertaken is to demonstrate that the concept will work and that the investment needed for the next phase of the programme will be justified. In due course, we would like to see a wide European involvement in the programme."

SATELLITE RECORDER FAILS

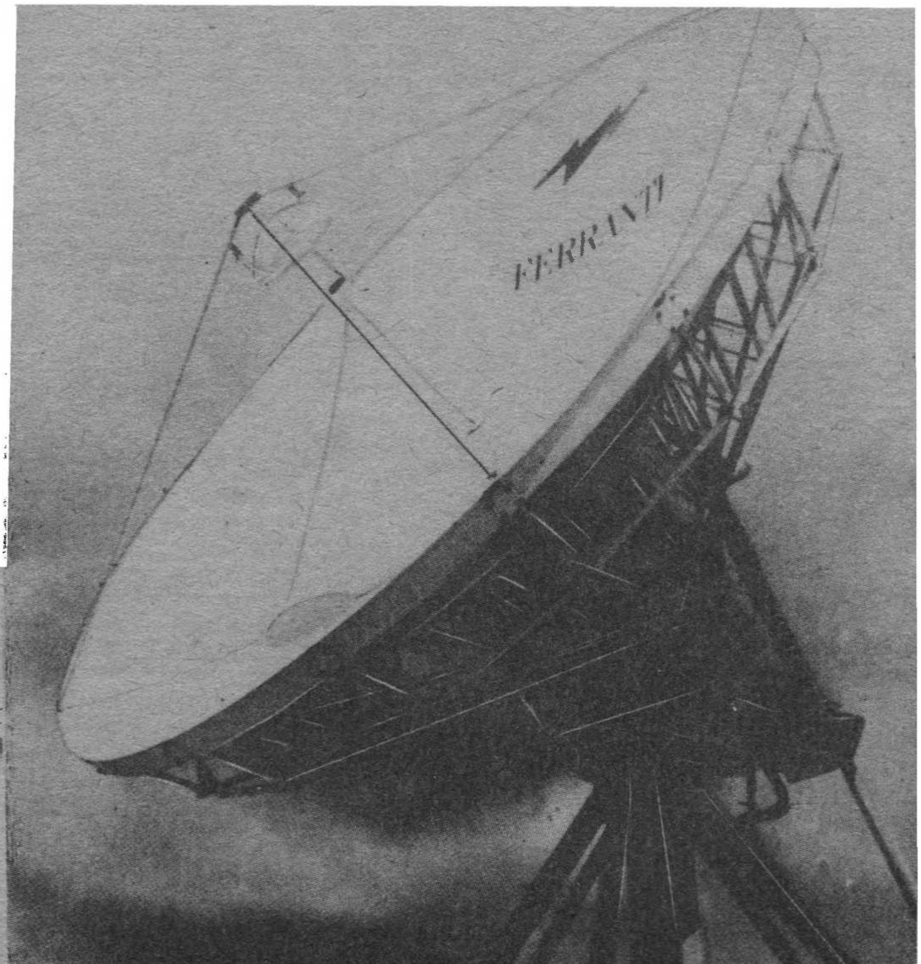
A tape recorder on the Spot 1 Earth observation satellite failed in late September. Spot 1 had experienced operational problems with the recorder, which is one of two, earlier in the mission which began after launch by Ariane in February of this year.

UK Industry Will Use BNSC Sponsored System

A civil satellite communications Earth terminal, custom-designed and manufactured by Ferranti for the British National Space Centre (BNSC), has been installed and commissioned at Defford in Worcestershire.

The 5.6 metre terminal is intended to support experiments with the Olympus satellite but can also be used as a general purpose experimental facility for testing and proving satellite payloads and new UK ground segment equipment.

The facility will be offered to UK industry to support experimental trials, demonstrations and prototype equipment testing and will provide support for high technology innovation in civil satellite communications.



Dr. Alan Shepherd (left), Managing Director of Ferranti Electronics and Mr. Roy Gibson, Director-General of BNSC, at the official handing over ceremony.

UP-DATE USA

New Solid Rocket Motor Design

Tighter-fitting joints, more flexible O-rings and heater bands to maintain acceptable temperatures in joints on cold launch days – these are key aspects to the new preliminary design for the Space Shuttle Solid Rocket Boosters.

A major change is the switching of the "capture feature" with an "interference fit" – an extremely tight one – that should stop hot gas "blow-by" altogether. A tongue-in-groove method of joining segments of the booster has always been used and the capture feature is a modification of that approach for the field joint, so called because it is linked in the "field" at Kennedy rather than at the factory.

A cutaway view of the original joint design shows a single-legged tang (the "tounge" of the joint) which fits into a U-shaped segment called a clevis (the "groove"), located beneath the tang.

In the new design the tang has a secondary leg, giving it an upside-down U-shape which fits over the inner leg of the clevis.

When the booster segment is actually viewed from above, the tang and clevis are circular in shape – a ring within a ring – and in the new design they form an extremely tight fit when joined together – the circle formed by the inner leg of the tang (the capture feature) is wider than the circle formed by the inner leg of the clevis, but the larger tang circle is forced inside the slightly smaller clevis circle for a tight fit. This difference in diameters causes the inner leg of the tang to exert pressure against the inner leg of the clevis, causing a metal-to-metal "interference fit" which the redesign team predicts will force the O-ring seals to maintain tight contact and stop any hot gas leakage.

The capture feature also includes a third O-ring – a departure from the original design of two for the field joint – which will assist technicians in making pre-launch pressure checks and will aid the "interference fit" in stopping gas leakage. If any "rotation" occurs – that is, if pressure from the burning propellant causes bulging of the sides of the segments and the further opening of gaps within the joints – the capture feature moves with the inner clevis leg and prevents hot gas from escaping.

An advantage of the new field joint design is that it allows the use of casings that have the original clevis configuration, since only new casings with upgraded tangs – those having capture features – will be required.

Synthetic rubber used in past O-rings of the field joint will be replaced with another material, such as fluorosilicone or nitrile rubber, having greater resiliency for a better seal. Additionally, two-kilowatt heater bands about an inch thick will be placed on the outside of the motor casings opposite the O-rings. Covered with insulation, the bands will maintain acceptable temperature levels within the joints even on very cold launch days. Power to the bands will be supplied by an external umbilical cord, which will separate from the boosters at the moment of launch.

For the case-nozzle joint, design changes include eliminating putty that fill the gap where insulation for the case and nozzle meet, narrowing the gap where metals meet, and eliminating the insulation gap altogether by reshaping it and applying an adhesive within it to bond it tightly together.

More resilient O-rings, which form **seals** where the metals of case and nozzle meet, will replace the older ones; and special "radial bolts" will be inserted through the two metals to join the case and nozzle more tightly together and prevent hot gases from escaping.

The old design utilised a large primary bolt that vertically fastened the two elements together as a joint; however, the joint was subject to "skip," small, quick slippage upon ignition of the booster. The skip caused the gap between the case and nozzle to open slightly before the O-rings could compensate by expanding from their normally compressed state and sealing off the hot gas leakage. The radial bolts, however, which will be inserted horizontally through the nozzle into the casing, will eliminate such slippage.

The nozzle redesign incorporates several changes as well. Principal among them is the addition of an extra O-ring at several critical points where metal and phenolic materials, which insulate the frame of the nozzle from the terrific heat of the flame during launch, come together to form joints. Furthermore, some of the phenolic parts themselves will be redesigned by changing the direction of their layers to provide greater resistance to erosion from heat.

In other changes, more insulation will be added to the factory joints in Utah. Because of their size, booster segments are shipped from Thiokol in units no longer than two centre segments at a time. They are linked by a factory joint which, unlike field joints, is covered completely by insulation and poses no substantial leakage problem. The added insulation called for in the redesign is to enhance safety factors and the reliability of the joint.

The redesign described above is the primary one selected for preliminary review. Several contingency designs are being carried out in parallel in the event the primary design turns out to be unsuitable.

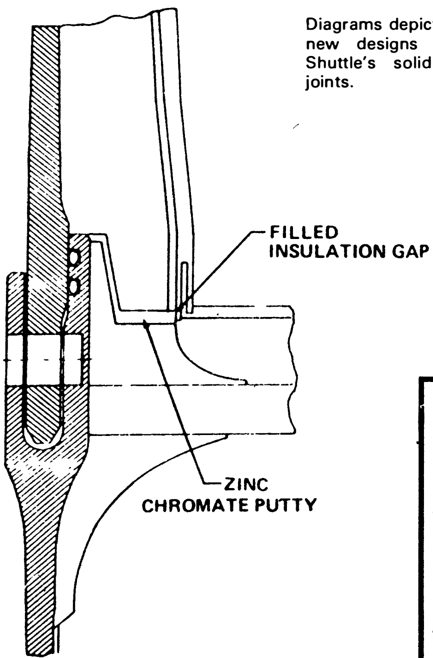
In addition, a completely new design not constrained to the use of existing hardware is being undertaken for contigency purposes in the event that something untoward happens to the preliminary design.

Full-scale tests are under way by Morton Thiokol,

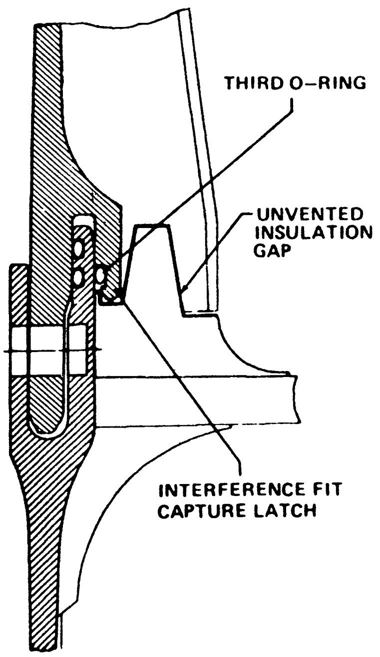
UP-DATE USA

which will conduct 20 firings of two booster segments containing only enough propellant for firing long enough to pressurise the new joint – about two seconds or less. With a separate set of dual segments, the Marshall Center will also conduct a similar series of 20 full-scale short-duration test firings beginning next April. At Thiokol an engineering test motor will be fired late this year, and in the autumn of 1987 the company will test two development motors and a final qualification motor.

Diagrams depicting the old and new designs for the Space Shuttle's solid rocket motor joints.



ORIGINAL DESIGN



NEW DESIGN

US BOOSTERS DELIVER TO ORBIT

Civilian and military satellites were put into orbit by United States Delta and Atlas rockets in September – the first successful launches since the series of successive failures earlier in the year.

A Delta two stage rocket, number 180, performed flawlessly on September 5 after lift-off from Cape Canaveral carrying two military satellites.

On September 17 it was the turn of the military controlled Vandenberg Airforce Base to continue the revived fortunes with the launch of an Atlas.

This time the payload was a civilian weather satellite, NOAA 10, which will replace the ailing NOAA 6 launched in 1979 and designed for an original life of just 20 months.

NOAA 10 is in a polar orbit providing detail crucial for hurricane tracking and for forecasting crops, forest and fishery conditions.

The Atlas rocket used for this launch was a converted missile, first deployed in 1961 and removed from its silo in 1965 to go into storage. The series of USA launch failures (Shuttle, January, Titan, April, and Delta, May) did not involve an Atlas but precautionary modifications to an electrical system – similar to the point of failure in the Delta – were made.

SHUTTLE LAUNCH MANIFEST

Date	Orbiter	Payload
		1988
Feb 18	Discovery	TDRS-C (Tracking and Data Relay Satellite)
May 26	Atlantis	Defence
July 28	Columbia	Defence
Sept 22	Discovery	TDRS-D
Nov 17	Atlantis	Hubble Space Telescope
		1989
Jan 19	Columbia	Astro-1 (Ultraviolet astronomy telescope)
Mar 2	Discovery	Defence
Apr 25	Atlantis	Magellan
June 2	Discovery	Defence Spacelab
June 21	Columbia	GPS-1, GPS-2 (Global Positioning System) and MSL (Materials Sciences Laboratory)
July 20	Atlantis	Defence
Sept 1	Discovery	Defence
Sept 21	Columbia	GPS-3, GPS-4 and MSL
Nov 1	Atlantis	Planetary opportunity
Dec 7	Discovery	SLS-1 (Space Life Sciences)
		1990
Jan 18	Columbia	Gamma Ray Observatory
Feb 15	Atlantis	Defence
Apr 20	Discovery	International Microgravity Laboratory
May 4	Columbia	GPS-5, Pathfinder and EOS-1
May 31	Atlantis	Defence
July 12	Discovery	Defence
July 26	Columbia	GPS-6, Skynet-4 and MSL-5
Aug 31	Atlantis	Defence
Oct 5	Discovery	Planetary Opportunity
Oct 25	Columbia	GPS-7, Insat-1D and TSS-1 (Tethered Satellite System)
Nov 15	Atlantis	Syncon IV-5 and long-duration exposure facility retrieval
		1991
Jan 17	Discovery	Atlas-1 (Atmospheric Laboratory)
Feb 14	Columbia	GPS-8, GPS-9, MSL-6: NASA/OSSA; SSBUV-1 (shuttle solar backscatter ultra-violet instrument)
Mar 1	OV105	Defence
Apr 4	Atlantis	GPS-10, Skynet-4 and EURECA((Europe retrievable carrier)

UP-DATE USA

EXTERNAL TANK STUDY

An American company is to study the feasibility of outfitting a Space Shuttle external tank as a space-based Gamma Ray Imaging Telescope to probe the source of gamma rays in the Universe.

Martin Marietta, which builds the giant external tank for the Space Shuttle programme, has determined that the spent tanks, 154 feet long and 27.6 feet in diameter, could be carried into orbit rather than discarded just before the Shuttle achieves orbit.

Once in space, any residual propellants could be expelled from the tank. Astronauts would then assemble telescope components within the aft section, a 96.7 foot long liquid hydrogen tank. The inside of the tank could be reached via an existing 36 inch aft manhole port or through a future modification of the tank.

The tank would be pressurised to provide the needed environment for the gamma ray detection system and components of the gamma ray imaging telescope could be carried in the Shuttle's cargo bay along with other payloads.

The telescope would require periodic maintenance and would probably orbit near the planned Space Station between 200 and 300 nautical miles above Earth.

NASA plans to conduct a separate gamma ray survey in the late 1980s using an orbiting Gamma Ray Observatory. The proposed Gamma Ray Imaging Telescope would follow up the work on the Gamma Ray Observatory with more accurate pointing studies.

SPACEHAB LAUNCH REQUEST

Spacehab, the American corporation developing pressurised middeck modules for the US Space Shuttle, is hoping to sign an agreement with NASA before the end of the year that will pave the way for a series of the first five Spacehab module flights.

In the agreement Spacehab has requested two flights in late 1989 and three in 1990, manifest space permitting.

Aeritalia (Torino, Italy), builders of the Spacelab modules for the European Space Agency (ESA), is scheduled to build the primary structures and thermal control systems of the first three Spacehab modules in 1987 and 1988. Phase B (advanced definition) on thermal requirements were completed by Aeritalia in June 1986. Phase B structures studies are now in progress. Phase A studies by Martin Marietta, Rockwell International MBB-ERNO and Aeritalia were completed in October 1985.

Spacehab which has received over 800 expressions of interest for module use from NASA, the US Defense Dept., US and foreign aerospace companies, foreign space agencies, and individual experimenters during the past year, has now started taking reservations from firms and organisations wanting module space.

Spacehab will double the available pressurised habitation volume on each Shuttle, provide additional living and working space for the crew, increase the manned volume on orbiter flights to service the three-year backlog of "middle type" experiments, and be used as a proving ground for space station systems and commercial space product research and development.

INTERNATIONAL SPACE REPORT

SPACE AID FOR THE WORLD

A call for a major new initiative to help under-developed countries benefit from Space was made in the opening address of the 37th International Astronautical Federation (IAF) Congress in Innsbruck, Austria, last month (October).

Mr. Roy Gibson, co-chairman of the IAF programme committee and Director-General of the British National Space Centre (BNSC), suggested to the 1,000 delegates that a form of 'Space Aid' could be started

The IAF Congress is one of the most important international space conferences of the year and Mr. Gibson's remarks, reported below, began a lively week of discussions and debate on a wide variety of space topics covering more than 60 sessions.

Mr. Gibson said he wanted to talk about how space could be better used to build bridges between the people of the world, a subject fundamental to the work of the IAF.

He also criticised the role of the popular press and TV which, he claimed, ignored the real stories of relevance to space in favour of "human interest" stories and "provocative articles" on national rivalry.

Mr. Gibson continued: "The race we should be interested in is not the so-called Space Race, but the human race. How can space help to solve Mankind's pressing problems?

"In those countries with a developing space programme the benefits are becoming increasingly widespread and the latest techniques are undoubtedly helping to solve real problems. But the gap between these and the less developed countries is widening; we are racing ahead with the development of more sophisticated space systems with less and less concern for the ways in which the opportunities can be made available to others.

"There is a need to apply space techniques to the solution of crucial, down to Earth problems – particularly those relating to famine and disease. Paradoxically the treatment of these problems does not necessarily require the expensive development of new space technologies or systems; a great deal can be done with technologies that many of us regard as old-fashioned. As our experts push forward the frontiers of knowledge – an inevitable and praiseworthy occupation – we often forget that the techniques we have already pioneered and mastered are being overshadowed and their potential forgotten.

"Perhaps in the drive for space commercialisation, we are forgetting the usefulness of relatively unsophisticated devices and techniques primarily because those whom they could help are in no position to pay for them. Indeed many cannot know that they exist and could be of practical use nor have they the necessary trained staff to run the systems.

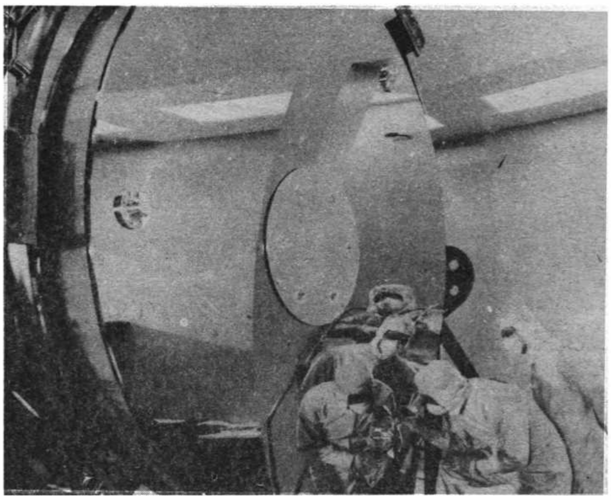
"It is tempting to believe that a new international organisation could help, but I am personally convinced that this is not the way to go. Making space benefits more available to people all over the world needs the cooperation of the public and private sectors in so many different forms and ways that no single governmental organisation could cope. It needs, however, the continued help of all those who are already working in the field and the enrolment of many, many newcomers.

"Perhaps, here, the IAF can be harnessed to the task. The IAF members have access to the cream of the world's space experts – not only the university scientists but the industrialists, and the space administrators. Can they not be persuaded to back a new crusade to make these opportunities available to all people?

"Is it not possible to induce our IAF to take a courageous step towards making these benefits more widely available? As I look about this auditorium I can see the talent that could make it happen. Can we not meet on this non-political and non-controversial ground to bring real life into the theme of this year's Congress? I frankly find this a more challenging enterprise than many of the awe-inspiring space programmes we shall be discussing this week.

"One way of ensuring that this year's theme "Space: New Opportunities for all People" is not forgotten would be to invite the IAF President and Bureau, and the General Assembly in which all the major actors on the space stage are represented, to consider how best to sponsor a new programme aimed at taking benefits to the people – a sort of Space Aid.

"I simply ask that we all spend more of our time and energy for those who are – in the parlance of our space scientists – many light years behind us."



TELESCOPE TIME FOR AMATEURS

Amateur astronomers in the United States will be given the opportunity to make observations with the Hubble Space Telescope (HST).

A small amount of observing time is being reserved for amateurs from periods of discretionary time which are set aside for astronomical targets of opportunity.

Dr. Riccarado Giacconi director of the Space Telescope Science Institute, has also said that amateur astronomers could use Space Telescope data, picture archives and conduct cooperative observation projects using their own telescopes for observations in concert with Space Telescope observations.

With a 94 inch mirror, the HST will be the largest astronomical telescope ever placed in space.

INTERNATIONAL SPACE REPORT

EXOSAT DISCOVERY

An international team of astronomers using ESA's X-ray satellite, EXOSAT, have found two stars that orbit each other every 11 minutes – by far the shortest known orbital period.

The two stars form a bright X-ray source 20,000 light years away in the constellation of Sagittarius called X1820-30 (named after its position in the sky). This system features a dying white dwarf star trapped in the gravitational grip of a neutron star.

Our galaxy contains about 50 X-ray sources similar to X1820-30, which are powered by gas falling from a nearby star onto a neutron star with a velocity of one third the speed of light. This releases an enormous amount of energy (10,000 times the output of the Sun) from the neutron star – which is only 10 km in radius. As the gas falls it becomes very hot and a bright source of X-rays is produced.

What EXOSAT discovered was an 11-minute low level pulsation in the X-rays from X1820-30. This orbital period is so short that the companion star that is circling the neutron star must be very small, only three times bigger than the Earth. This can only be a white dwarf, made of pure helium. These two stars would easily fit in between the Earth and the Moon and yet the total mass of the system is one and a half times that of the Sun.

A vital clue to the formation of this remarkable double star comes from its location in the core of the globular cluster NGC 6624, a dense conglomeration of very old stars. While in our part of the galaxy there is virtually no chance of two stars colliding, in a globular cluster the stars are a million times closer together.

One suggestion is that the binary system X1820-30 formed when a neutron star and a red giant (a star like the Sun nearing the end of its life) 'collided'. The neutron star would then orbit inside the red giant's atmosphere spiralling inwards, the energy release being sufficient to rapidly blow away the outer layers of the red giant to leave behind only its tiny helium core – a white dwarf.

EXOSAT was launched by a US Delta rocket in May 1983 and ceased operations just under three years later in April of this year.

SATELLITE'S FIRST RESCUE

The National Oceanic and Atmospheric Administration NOAA-10 satellite was instrumental in saving the lives of four people after their airplane had crashed into a lake in northern Ontario, Canada. NOAA-10, launched on September 17, is the latest addition to the highly successful COSPAS-SARSAT Satellite-aided Search and Rescue programme.

The aircraft's emergency beacon was relayed by the NOAA-10 to ground stations in Ottawa and Washington which were conducting tests on the satellite when the emergency signal was received on September 23 at 7:28 pm EST.

The Ottawa ground station automatically located the aircraft beacon and transmitted the location to the Canadian Mission Control Centre at CFB Trenton. Rescue forces from the Edmonton Rescue Control Centre were alerted and rushed to the crash site. Four people were rescued, two with serious injuries and one with minor injuries. The injured people were air-lifted to hospital in Winnipeg and Red Lake.

The NOAA-10 launch brings the total number of COSPAS-SARSAT satellites to five, two from the US and three from the USSR. The SARSAT packages, supplied by Canadian Astronautics Ltd., are secondary payloads in both the US and Russian satellites.

POLAR PLATFORM STUDY

UK firm Logica is due to complete a study this month (November) on the feasibility and cost-effectiveness of servicing in orbit the Columbus polar orbiting platform elements of the International Space Station programme.

The study, has been examining operations involving the American Space Shuttle, European Ariane-5 and Hermes, and British Hotol launcher systems.

NEW DIRECTOR

Mr. Don Hardy has been appointed Director for Earth Observation in the Directorate of Policy and Programmes at the British National Space Centre. At present he is directing an interdepartmental study of the utilisation of the Space Station, a report of which he will present at the end of 1986. Mr. Hardy will be responsible for the formulation of policy on Earth observation and will also lead the UK delegation to ESA's Earth Observation Programme Board.

CHINESE LAUNCH

A formal launch reservation agreement for a US communications satellite to be launched by a Chinese rocket is expected to be finalised by the end of this year.

Western Union, the company which lost a satellite when it failed to reach orbit after deployment by the US Space Shuttle in 1983, has already signed a letter of intent to launch its Westar 6-S satellite on the Chinese Long March 3. Launch from China's new Xichang site would be before the end of March 1988.

INTERNATIONAL SPACE REPORT

SATELLITE DIGEST – 196

Robert D. Christy

Continued from the Sept/Oct 1986 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the setellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1757, 1986-45A, 16772.
Launched: 0745, 11 June 1986 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system, and a 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and mass around 6000 kg.
Orbit: 180 x 224 km, 88.60 min, 82.34 deg, manoeuvrable.

COSMOS 1758, 1986-46A, 16791.
Launched: 0444, 12 June 1986 from Plesetsk, by A-2 or F-2.
Spacecraft data: Possibly a truncated cone with a pair of sun seeking solar panels at right angles to the centre of the body, and a sensor array at one end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 631 x 669 km, 97.79 min, 82.49 deg.

COSMOS 1759, 1986-47A, 16798.
Launched: 2004, 18 June 1986 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stablisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 969 x 1003 km, 104.88 min, 82.93 deg.

COSMOS 1760, 1986-48A, 16800.
Launched: 1030, 19 June 1986 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may have been carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and mass around 6000 kg.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 349 x 415 km, 92.23 min, 70.00 deg.

MOLNIYA-3 (29), 1986-49A, 16802.
Launched: 2109, 19 June 1986 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end ofthe vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially 616 x 40675 km, 736.84 min, 62.90 deg, then lowered to 620 x 39753 km, 718.15 min, 62.92 deg to ensure daily repeats of the ground track.

COSMOS 1761, 1986-50A, 16849.
Launched: 0116, 5 July 1986 from Plesetsk by A-2-e.
Spacecraft data: Probably similar to the Molniya satellites, in which case it has a cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries sensors and a solar panel array set in a plane at right angles to the main axis of the body. Stabilisation is probably by the use of momentum wheels. The length is about 4 m, the maximum diamter about 1.6 m, and the mass aroung 1800 kg.
Mission: Part of the USSR's ballistic missile early warning system.
Orbit: Initially 583 x 39334 km, 708.93 min, 62.92 deg then raised to 585 x 39757 km, 717.53 min to ensure daily repeats of the ground track.

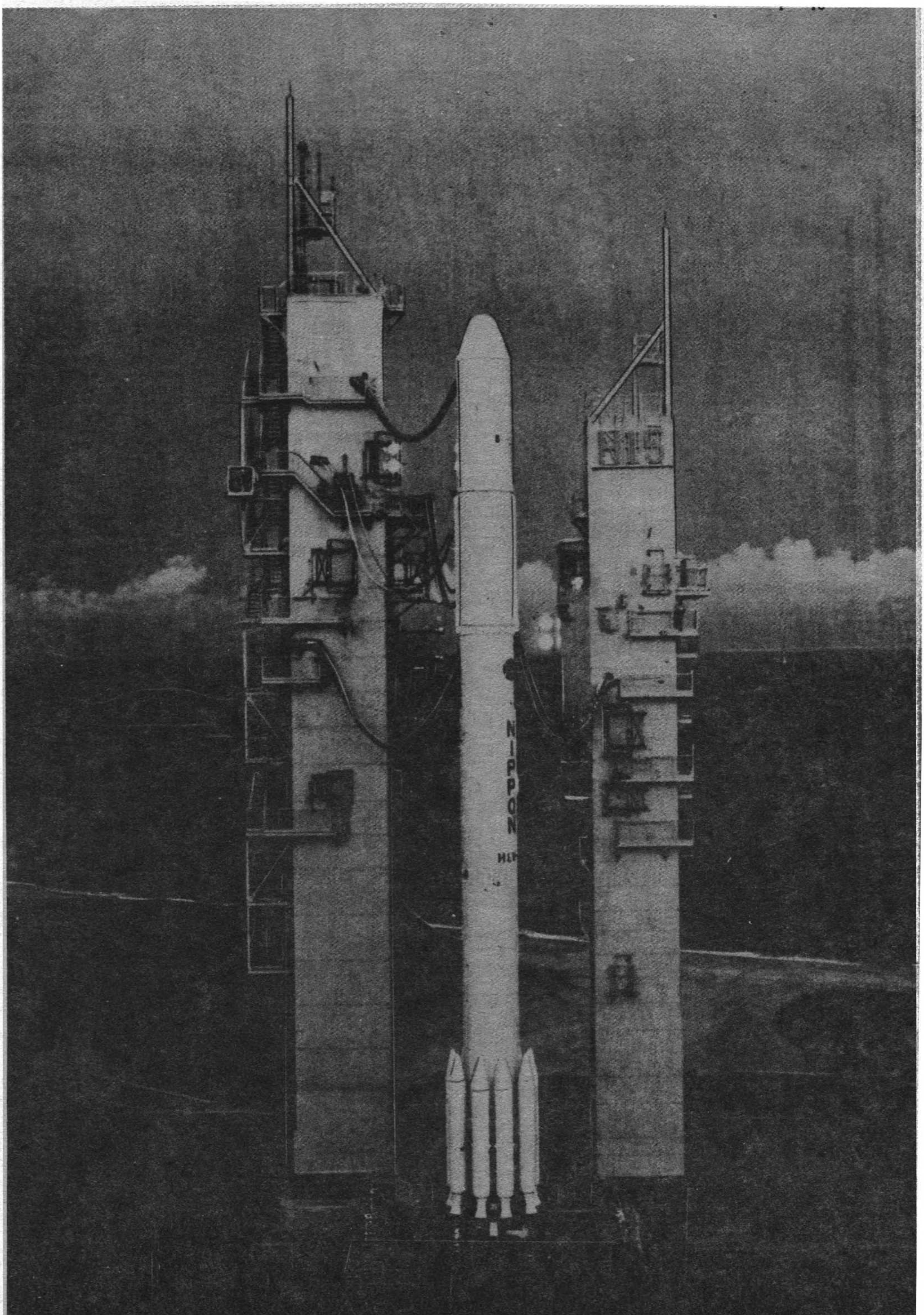
COSMOS 1762, 1986-51A, 16855.
Launched: 0800, 10 July 1986 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system, and a 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Photo-reconnaissance, recovered after 14 days. All or part of the payload was an Earth resources package operating under the 'Priroda' programme.
Orbit: 259 x 272 km, 89.89 min, 82.55 deg.

COSMOS 1763, 1986-52A, 16860.
Launched: 0423, 16 July 1986 from Plesetsk by C-1
Spacecraft data: Possibly a cylindrical, solar cell covered body, 2 m long and 2 m diameter with mass around 700 kg.
Mission: Military communications using a store/dump technique.
Orbit: 757 x 807 km, 100.54 min, 74.04 deg.

COSMOS 1764, 1986-53A, 16861.
Launched: 1230, 17 July 1986 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 173 x 341 km, 89.66 min, 64.91 deg, maneouvrable.

COSMOS 1765, 1986-54A, 16874.
Launched: 1230, 24 July 1986 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 356 x 415 km, 92.30 min, 72.87 deg.

Japan's H-1 test vehicle liffted off from the Osaki launch site, Tanegashima, on August 13 carrying three payloads to orbit - the Experimental Geodetic Satellite, the Japanese Amateur Radio satellite and the Magnetic Bearing Flywheel Experimental System. The picture opposite shows the two-stage rocket prior to launch. *NASDA*


NIPPON

SOVIET SCENE

Design Features of the Mir Space Station

Diagrams and text by Dietrich Haeseler

With the launch of the Mir space Station last February the Soviets began to build the first modular space station in near Earth orbit. The station complex will eventually consist of several elements:

- The Mir basic station.
- Large scientific modules such as Cosmos 1443 and 1686.
- Small scientific modules such as Cosmos 1669.
- Soyuz-TM crew transporters.

The Mir Basic Station

In general Mir has the same appearance as the former Salyut 6 and 7 stations. The mass seems to be around 20 t (1t = 1000 kg) while Mir, at 13.5 m, is about one metre shorter than Salyut.

Whereas Slayut had three solar cell arrays, each with an area of 20 m^2, Mir was equipped at launch with only two arrays but an area of 38 m^2 for each array, 76 m^2 in total. A picture showing Mir during check-out in the Tyuratam cosmodrome indicates that Mir has an attachment for a third solar array in the same place the Salyuts have their third array. An additional solar array for Mir could be delivered in a module and mounted to this attachment point by cosmonauts during an extravehicular activity (EVA).

The Mir solar arrays seemed to be folded at launch in a different way than the Salyut arrays. A beam extending radially from the joint between the array and the station forms the backbone, from which panels fold out to both sides. The beam itself is folded at launch to the wall of the medium diameter cylinder of Mir under the aerodynamic shroud. This new mechanism could allow the arrays to be retracted in orbit, thus avoiding collisions with modules docked to lateral ports.

Docking Systems

Mir provides six possibilities for docking other vehicles, two axial and four lateral docking systems. All vehicles will perform rendezvous and docking with one of the axial ports initially and may then be moved to one of the four lateral ports. This would be performed using a manipulator arm, attached to a module, by bringing it into contact with one of two mechanical fixpoints situated between the axial and two adjacent lateral ports (figure two). The manipulator would then swing around to place the docking system of the module in front of one of the lateral docking systems using its fixpoint as the centre of rotation.

The Mir docking units do not carry a strengthening ring. Such a ring was applied to Salyut 7 to accept the high bending loads arising from the docking of two large vehicles. Results of the Resonance experiment, evaluating the dynamics of the docked Salyut 7 and the module Cosmos 1443, may have shown that such a ring is not necessary.

Internally, Mir is equipped to provide living quarters to allow up to six cosmonauts, male and female, to stay permanently on the station.

Large Scientific Modules

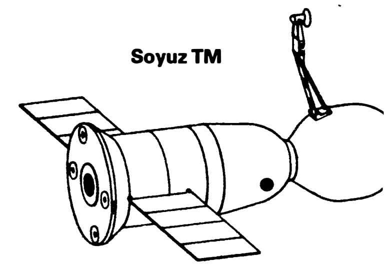
Large modules have been tested during the flights of Cosmos 1267, 1443 and 1686 in connection with Salyut 6 and 7 (figure 3). There are two versions, either with or without a descent compartment to recover payloads, like Cosmos 1443 and 1686, respectively. If the module carries no descent compartment, it could be instrumented with heavy scientific apparatus, such as a radio telescope.

It is unclear whether these large modules can be docked to the axial ports only or to the lateral ports as well. It may be difficult to attach a large module with solar panels to a lateral port because of the danger that the solar panels of the module may collide with the solar arrays of Mir. The large modules are not designed as free-flyers.

Cosmos 1443, a module with a descent compartment, had a cylinder of 2.9 m diameter, with some tanks and other equipment added to the outer surface. A mockup in the cosmonauts' training centre shows a different design for a large module without the descent compartment, carrying docking units on both sides. No manoeuvring engines are visible on the mockup, but the module will have a system to perform the approach to Mir and, perhaps, be able to hold the complex in proper orbit by some engine kicks to compensate for altitude loss due to drag in the thin atmosphere.

A first operational module is expected to be launched by the end of this year. The modules Cosmos 1267, 1443 and 1686 launched so far did not carry built-in scientific instrumentation. For the new module an X-ray package of about 600-800 kg is being prepared, including an ESA gas scintillation proportional counter instrument called HEXE. The module provides gyro-stabilisation for the whole complex in unmanned, automatic flight to achieve accurate pointing for the telescopes.

Concluded on page 400.



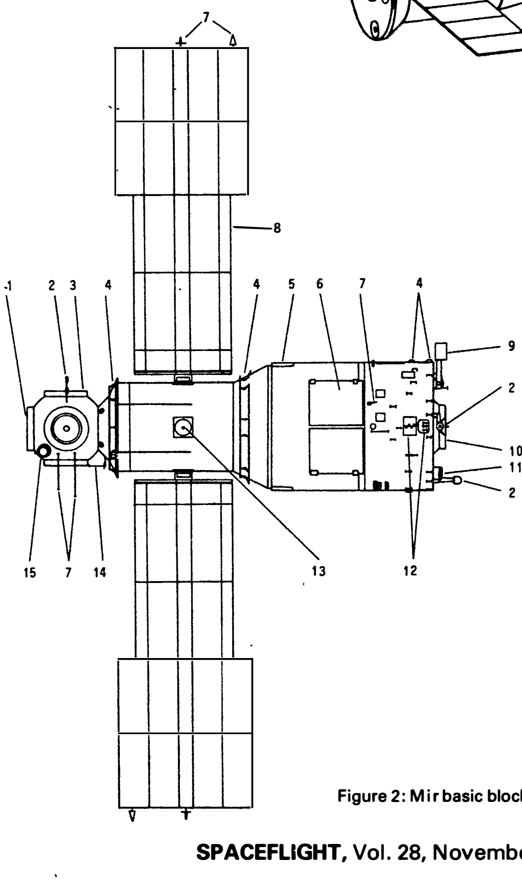


Figure 2: Mir basic block.

SOVIET SCENE

Table 1: Data for the Space Complex Elements:

	Mir	Large Module with DC	Large Module w/o DC	Small Module	Soyuz-TM	Progress
Mass (t)	20	20		7	7	7.02
Length (m)	13.5	13	(6.5)	7	6.98	6.98
Max. diameter (m)	4.15	4.15		2.7	2.72	2.72
Habitable volume (m^3)	90	50		10	10.3	6.6
Solar cell arrays	2	2	(–)	(2)	2	0
span (m)	24	16	(–)	(10.6)	10.6	–
total area (m^2)	76	40	(–)	(11.5)	11.5	–
electr. output (kW)	5.5	3	(–)	(0.8)	0.8	–
Payload at launch						
crew (persons)	0	0		0	2-3	0
cargo (kg)		3000	5000	(2000)	250	1920
propellant (kg)		1000	3000	–	–	670
Descent Compartment (DC)						
mass (kg)	–	5000	–	(–)	3200	–
payload (kg)	–	500	–	(–)	150 + 3 cosmon.	–
No. of docking systems	6	1	2	1	1	1

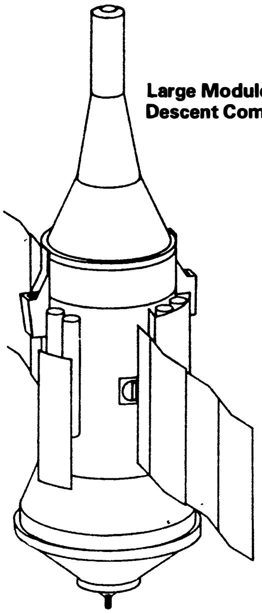
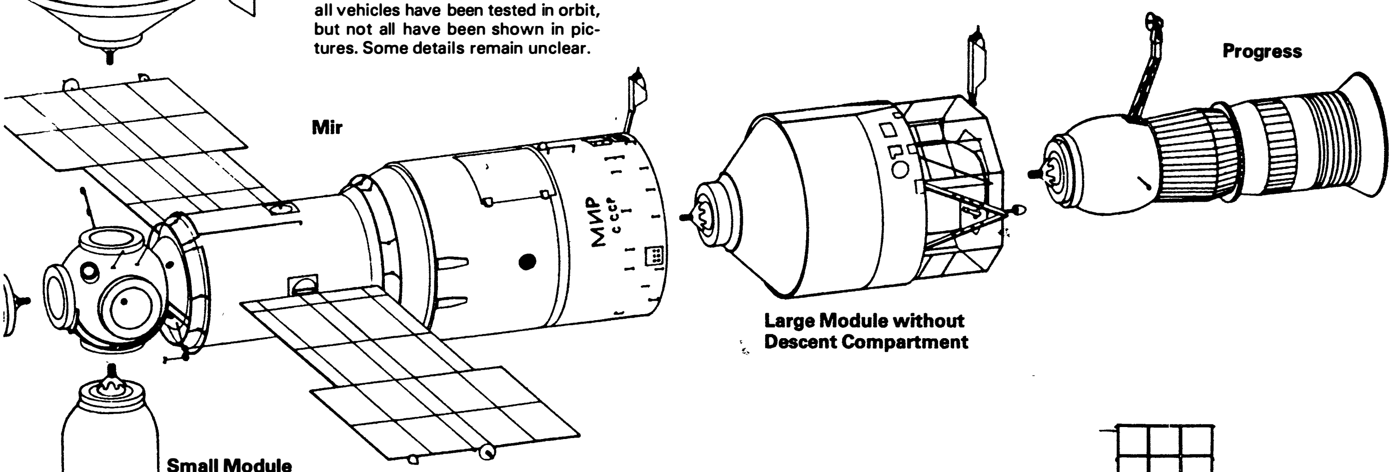
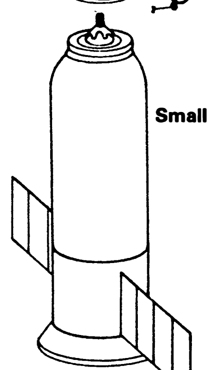


Figure 1: A conceptual diagram of vehicles involved in the Mir modular space station complex. Examples of all vehicles have been tested in orbit, but not all have been shown in pictures. Some details remain unclear.





Notes to Figure 3.

Cosmos 1443 represents a large module with a descent compartment (DC) which was docked to Salyut 7. The version without the DC is probably not developed from this module but looks like the one in Figure 1.

1. Retro burn engine.
2. Braking engines for soft touchdown.
3. Descent compartment, 500 kg payload capacity.
4. Attitude control thrusters.
5. ODU manoeuvering engines, 2 x 3000 N thrust.
6. Solar cell arrays, 2 x 20 m^2
7. Antenna for aduio transmission.
8. Strengthened docking system used in connection with Salyut 7; if such a module is to dock to Mir, most probably it will not have such a strengthened unit but a normal one.
9. Strengthened docking probe, can be applied to Mir, too.
10. Propellant tanks (eight places).
11. Telemetry antenna.
12. Rendezvous radar.
13. Aerodynamic shroud attachments (4 places)
14. TV camera for approach control.
15. Infrared horizon sensor.
16. Search antenna for rendezvous.

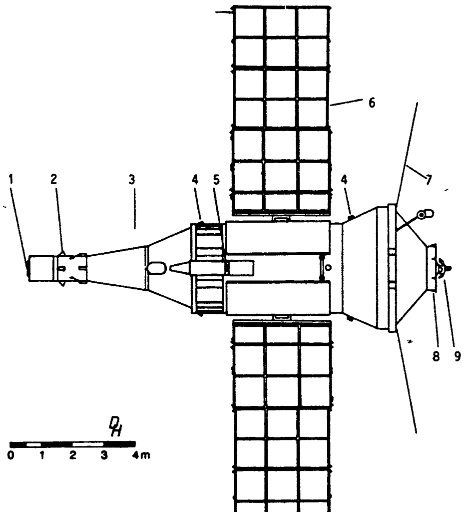
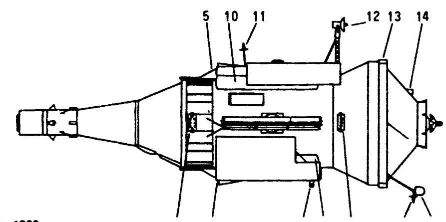


Figure 3: Large Module with descent compartment.



Notes to Figure 2.

1. Forward axial docking system.
2. Rendezvous antenna.
3. Lateral docking systems (4 places).
4. EVA handholds.
5. Aerodynamic shroud attachments (4 places).
6. Micrometeorite detectors or heat rejection radiators.
7. Telemetry antenna.
8. Solar cell arrays, 2 x 38 m^2.
9. Directional telemetry antenna for using a relay satellite.
10. Rear axial docking system.
11. ODU manoeuvering engine, 2 x 3000 N thrust.
12. Attitude control engines, 32 x 140 N thrust.
13. Attachment for a third solar cell array /16/.
14. Docking target for the forward axial docking system.
15. Mechanical fixpoint for redocking (4 places).

SOVIET SCENE

Halley's Comet: The Vega Story

by Roald Sagdeyev*

Project Vega was an ambitious Soviet mission to send two spacecraft to the planet Venus and then on to a flyby of Comet Halley in March of this year. In the following article Roald Sagdeyev, head of the Vega Project, discusses some of the discoveries and new information that has already come to light as a result of the data and thousands of pictures returned from the Halley encounter.

Comets are celestial bodies which come from remote corners of the Solar System. It is assumed that there are some 100 billion comets in the comet cloud circling the Sun at distances which are ten thousand times larger than the distance between the Sun and the Earth. The majority of them stay there for billions of years, others leave the Solar System for ever, while still others like Halley's comet move into its interior regions or even settle in orbits with a relatively small period of revolution.

Since the comet cloud probably formed at the same time as the Solar System, by studying cometary matter we can obtain data on the primordial material from which the planets and their satellites were formed four and a half billion years ago.

A long time will pass before we get a practical technical opportunity to make a landing on a comet's nucleus, mainly because the approach speed of space vehicles closing upon such objects is so great – in the case of Halley's comet it was 78 kilometres per second. Another point is the impossibility of flying too close to a comet since cometary dust, consisting of particles which may be a fraction of a micron to hundreds of microns in diameter, is too dangerous for any spacecraft with such approach speeds.

Spacecraft Instrumentation

The distance at which the Vega probes passed Halley (just under 10,000 km) was chosen on the basis of earlier notions about the qualitative characteristics of cometary dust. But how could the nucleus be studied from such a distance? Two approaches were used: remote-control measurements with optical instruments, and direct studies of cometary matter (gas and dust) escaping from the nucleus and crossing the probe's trajectory.

Optical instruments were mounted on a special platform which turned during the flight and automatically tracked the nucleus. The platform was jointly designed by Czechoslovak and Soviet engineers and was built in Czechoslovakia. Three research experiments were carried out with the instruments mounted on the platform. One of them was TV-filming of the nucleus using a system jointly designed by Soviet, Hungarian and French specialists.

Another instrument, an infrared spectrometer, was used in two simultaneous experiments: in measuring the flow of infrared radiation from the nucleus (and thus gauging the temperature of its surface) and the spectrum of infrared radiation by the internal near-nucleus parts of the coma on wave frequencies from 2.5 to 12 microns to find out its composition. Scientific supervision of these experiments was conducted by Soviet and French specialists and the instrument itself was manufactured in France.

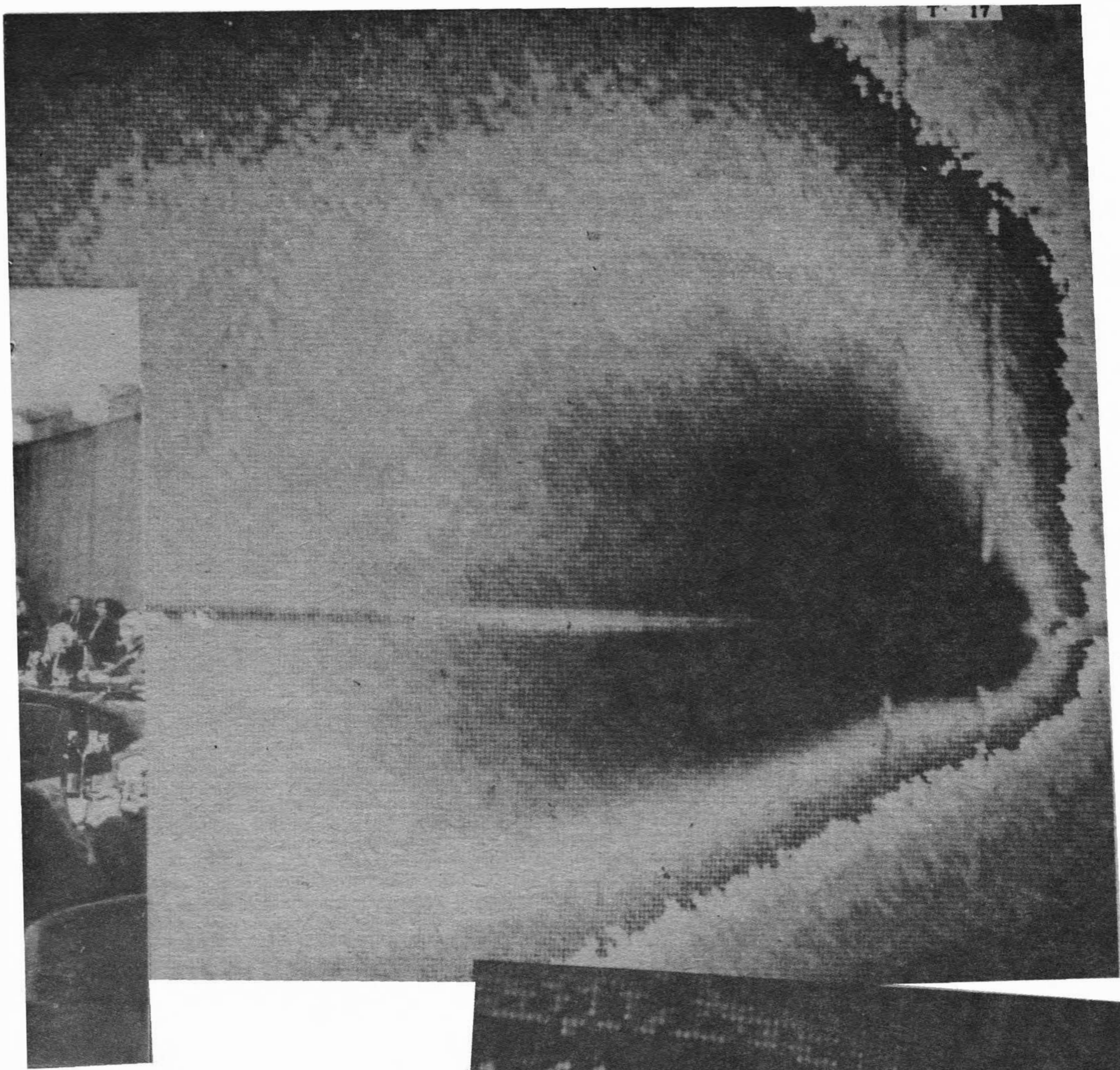
The third instrument on the platform was a three-channel spectrometer which obtained the spectrum of the radiation by the coma's interior on wave lengths from 2,800 to 18,000 angstroms. It was jointly designed and produced by Soviet, Bulgarian and French specialists.

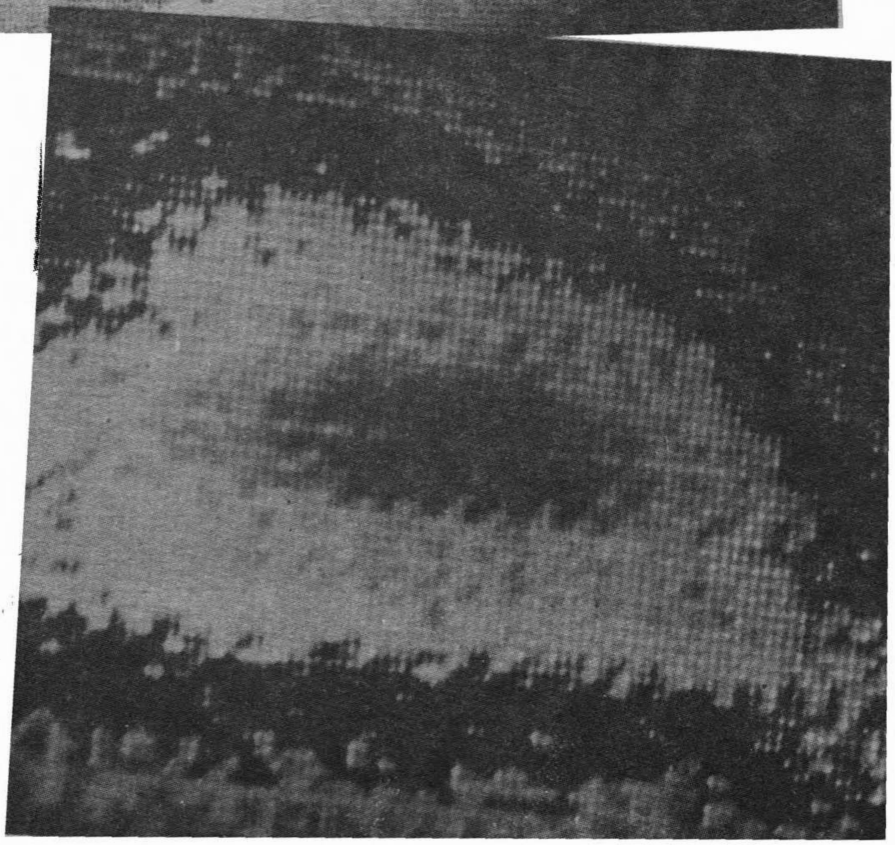
Building Up a Picture

So what image of Comet Halley's nucleus did the optical instruments get? It has turned out that it is an oblong monolithic object of irregular shape. Its size is 14 km long and about seven km across. Every 24 hours, when the comet is in perihelion, several million tons of vapours escape from its nucleus. Calculations show that for this "productivity" evaporation must occur from the entire surface, which could happen if it were a solid ice-block.

The instruments on the Vega probes have established, however, that the surface of the nucleus is black (reflecting ability less than five per cent) and hot (approximately 100 degrees Cel-

**Roald Sagdeyev is the Director of the Institute of Space Studies of the USSR Academy of Sciences.*





An international gathering (above left) involving scientists from Austria, Bulgaria, Czechoslovakia, France, Germany, Hungary and Poland to discuss results from Project Vega. *Novosti*

The nucleus of Halley's comet and surrounding layers can be clearly picked out in the two false colour images above and right. In total the Vega spacecraft returned some 12,000 pictures of the comet. Vega 1 passed within 9,000 km of the nucleus and Vega 2 within 8,200 km.

sius). The resultant picture seems incredible and controversial. Even so, it fits into a simple model which can be compared to a packed springtime snow-drift. It is a conglomerate of ice and refractory particles, separated from the outside space by a layer of black porous matter with low heat conductivity. This layer takes on solar radi-

SOVIET SCENE

Josette Runaveau, Director of the French participation in Project Vega. *Novosti*

ation, partially reflects it in the infrared range and conveys the rest of it inside the ice conglomerate. Molecules of vapour which form as a result of the latter's evaporation diffuse outward through the pores and escape from the comet, taking along small particles of dust.

From time to time the surface layer bursts open in some places (when the layer gets too thick and the pores get clogged), creating "active zones" with an extra-powerful efflux of matter. The porous layer is only a few millimetres or possibly centimetres thick and it is replaced very quickly, in about 24 hours. The exterior particles get loose and are carried away with gas, while new ones stick to it from inside.

The low reflecting ability of the nucleus may be an indicator that the composition of the surface layer is similar to that of carbonaceous chondrites, a class of meteorites which are the oldest of all and least affected by time and other influences.

Nucleus Composition

Important data on the composition of the nucleus was obtained by means of direct measurements of the chemical composition of dust, gas and plasma while the probes were flying through the coma. These measurements have shown that in terms of relative content the most common element in the gas flows escaping from the comet is water vapour, although there are many other components, both atomic (hydrogen, oxygen, carbon) and molecular (carbon monoxide and dioxide, hydroxyl, cyan and others). Spectral patterns of about ten molecular components (aforementioned and others) were registered in the interior coma with the help of the infrared and three-channel spectrometers.

A subject of special interest is which of these molecules are "paternal" or occur inside the nucleus. It appears that two such principal elements are

The first pictures from Vega 1 of Halley's Comet were studied at the international consultative group of space agencies in early March. *Novosti*

water and carbon dioxide, although there are many indicators of the presence of other and, notably, organic molecules in the nucleus.

The nucleus matter is probably a clathrate: ordinary water ice with other molecules fused into its crystalline lattice. Mixed with this clathrate are meteoritic particles of both rock and metallic origin.

The chemical composition of such solid particles, which had once been part of the nucleus but had escaped from it under the pressure of gas flows, was measured along the trajectory of the Vega 1 and Vega 2 probes by means of a dust-impact mass spectrometer. This fairly sophisticated device analysed the chemical composition of plasma clouds occurring at impact with particles flying at about 80 kilometres per second. All in all, the composition of about 2,000 individual particles was studied. It proved to be very complex and non-uniform. There were particles dominated by metal components such as sodium, magnesium, calcium, iron and others, and there were silicate-based specks, too. The spectra of many particles feature oxygen and hydrogen peaks, attesting to the presence of water molecules. Finally, there were dust specks with a fairly high content of carbon. This wide diversity of particles points to the complex thermal history of the primordial material of the Solar System.

Comet Formation

As a result of the Vega and other expeditions to Comet Halley in early 1986 scientists have for the first time seen the comet's nucleus and obtained a vast volume of data on its composition and physical characteristics. A rough sketch has been replaced with a

SOVIET SCENE

Roald Sagdeyev, Director of the Space Research Institute of the USSR Academy of Sciences, speaks to journalists at a Vega news conference.
Novosti

real picture of that natural object which was never observed so directly before. Outwardly, it somehow resembles the Martian satellites, Phobos and Deimos, although some of the smaller satellites of Saturn and Uranus may prove even closer analogues.

All this fits into the theory which assumes that cometary nuclei were formed relatively near the Sun, somewhere around Jupiter and Neptune, but were then hurled far away in the process of the formation of those planets. That such a monolithic object could have formed in interstellar space now seems much more improbable.

Apart from the investigations of the chemical composition of dust particles, the probes studied the quantitive characteristics of the dust flow, with special counters gauging the number of collisions with particles of varying mass. The experiments with dust counters have shown that during the passage near the Sun about a million tons of cosmic dust escape from the comet's nucleus every 24 hours. This is a non-uniform flow which is heavier over the active zones of the nucleus and, in addition, there are effects associated with the varying impact of light pressure on the movement of particles of various size and mass. Another surprising discovery was the pattern of particle distribution by size, with an abnormally large share of extra-small particles only a hundredth of a micron across.

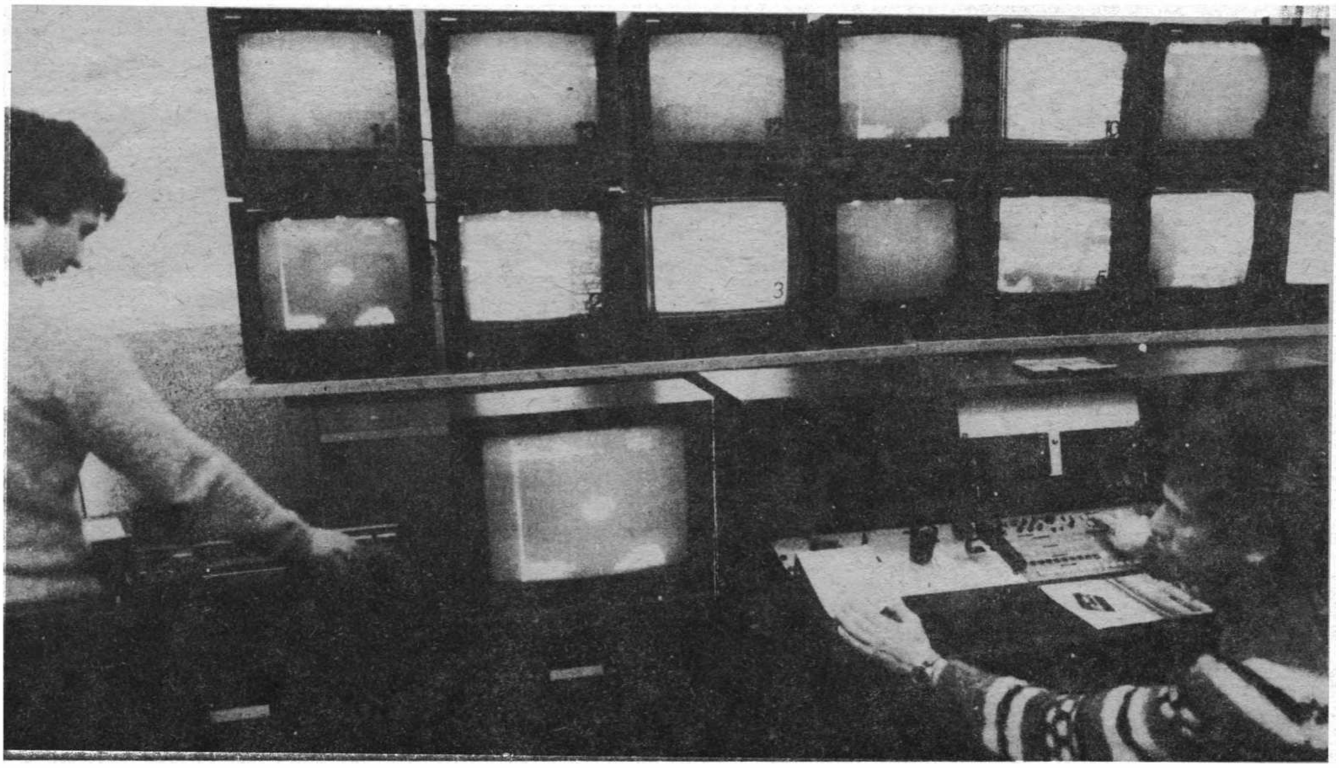
Impact Wave

The gas evaporating off the comet's nucleus and expanding into interplanetary space at about one kilometre per second is eventually fully ionized by solar radiation. This results in a giant plasma cloud about a million kilometres wide. It becomes an obstacle in the way of the ultrasonic flow of solar wind which is essentially plasma from the overheated corona of the Sun. As a result of this, a kind of impact wave develops in the flow of solar plasma infront of the comet, which is dissimilar in structure from the well-studied impact waves infront of the Earth and other planets. It was studied by instruments on the plasma complex of the Vega probes. The complex comprised a plasma energospectrometer, a magnetometer, low- and high-frequency plasma wave analysers and a detector of charged energy particles.

After passing the impact wave, solar wind slows down and flows around the denser internal part of the comet's coma, capturing particles of ionized cometary gas. This process is directly responsible for the formation of the extended plasma tail of the comet which differs from the dust tail with its fine jetty structure which is clearly distinguishable on photographs.

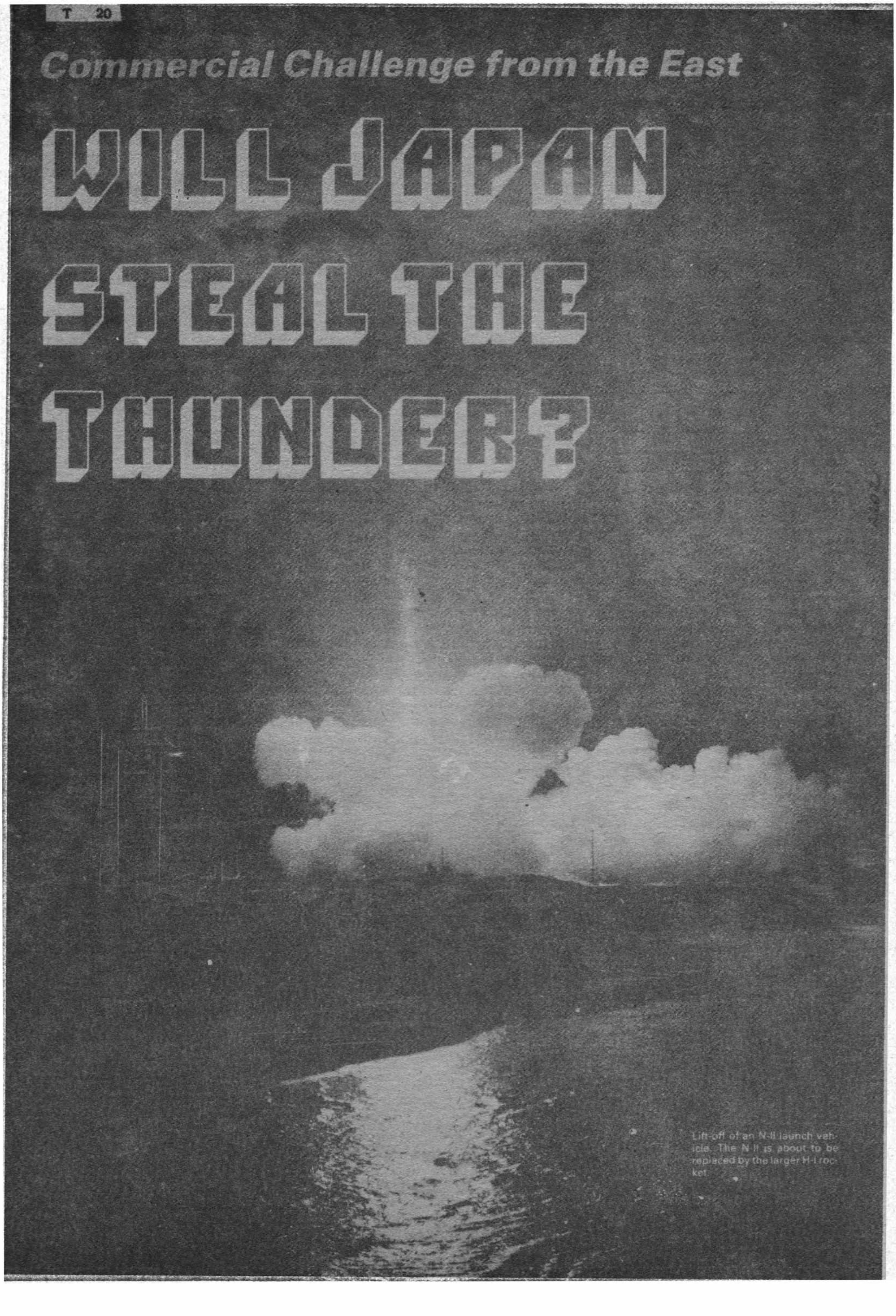
Direct measurements of plasma and plasma waves inside the coma have shown that the formation of cometary plasma cannot be explained only by the ionization of cometary gas by solar radiation. A large contribution to the ionization of that gas is made by energetic electrons which form as a result of the interaction between solar and cometary plasma. This discovery will help understand the laws of plasma formation and gas emanation not only in comets but also in various other astrophysical objects where the interplay between different types of plasma is of crucial importance.

The control panel for regulating television transmissions and showing film about individual instruments used in the Halley Comet study. *Novosti*



Commercial Challenge from the East

WILL JAPAN STEAL THE THUNDER?

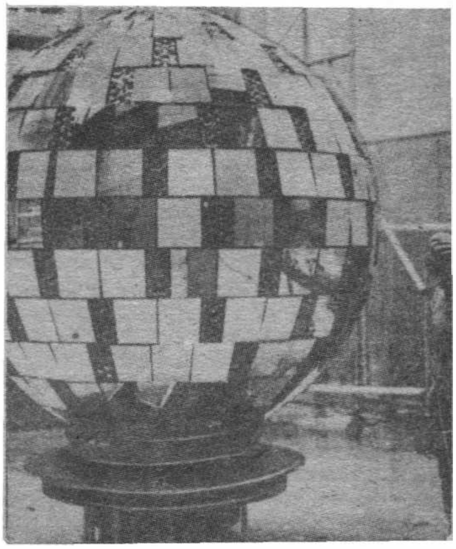


Lift-off of an N-II launch vehicle. The N-II is about to be replaced by the larger H-I rocket.

JAPAN

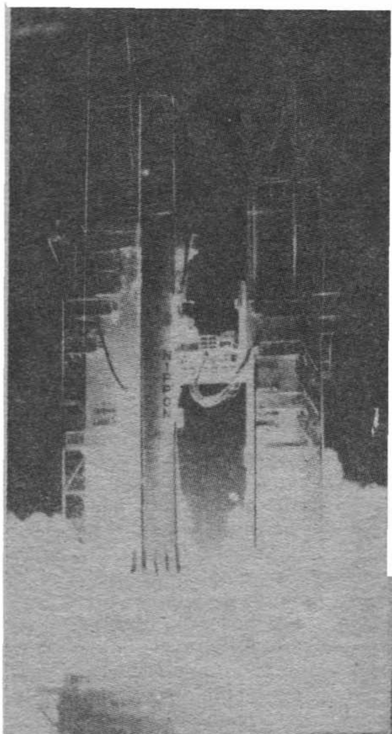
Successful Launch Heralds A New Era

Report compiled and written by:
Stephen Byford, Clive Simpson and Nik Steggall



The Experimental Geodetic Payload (EGP) seen before its launch on August 13.

The launch of Japan's newly developed H-1 booster on August 13 put the West back on the space map following successive Space Shuttle, Titan, Ariane and Delta failures in the first half of 1986. For Japan, a country which has already proved its tenacious ability to capture massive consumer markets in the electronics and car industries, it also marks the dawn of a new era - major consumer companies like Nissan and Mitsibushi are now turning their attention to rockets and satellites.



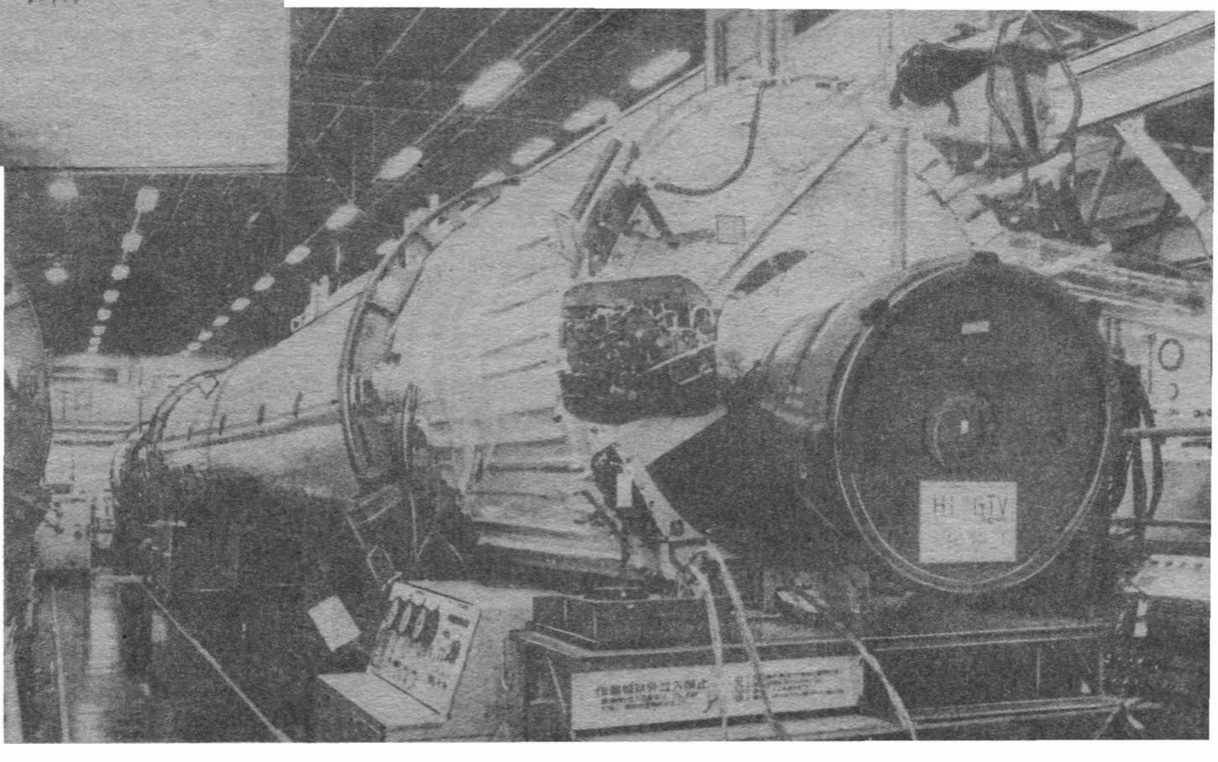
Japan, currently developing three expendable boosters, the largest of which will rival Europe's Ariane 5, and a series of commercial and scientific satellites including vehicles for missions to Venus and the far side of the Moon, has launched some 30 satellites since 1970 under a consistent yet moderately funded space programme.

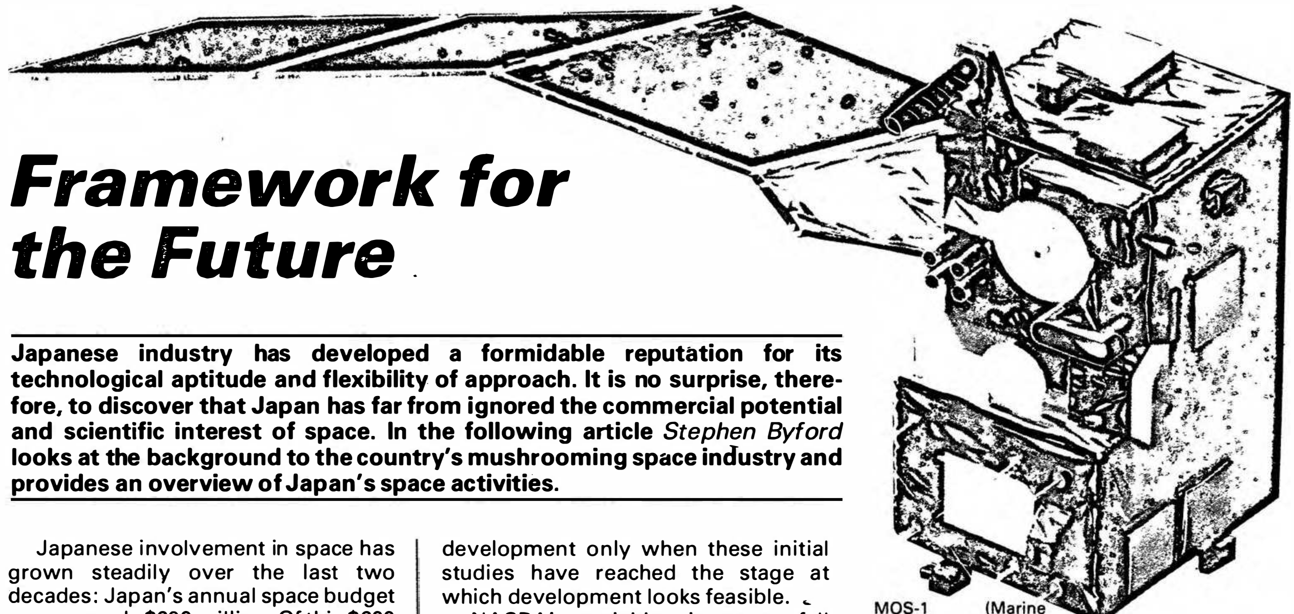
The latest of these were the three payloads (the Experimental Geodetic Satellite, Amateur Radio Satellite and the Magnetic Bearing Flywheel Experimental System) on the first test flight of the H-1 rocket.

Manned space flight is also regarded as a key area and here too Japan is planning significant involvement - a Japanese Spacelab mission is scheduled after US Shuttle flights resume, an autonomous module for the international Space Station and the possibility of its own man-rated Shuttle in the late 1990's all figure prominently.

The typically thorough and fastidious approach of the Japanese which has already brought success in a diverse variety of fields is now ensuring that, both in terms of international cooperation and competition, the country's fledgling space effort is creeping inexorably up the space league.

The H-I two-stage test vehicle (left) lights up the pre-dawn skies at the Osaki launch site, Tanegashima, on August 13, 1986. The rocket made a perfect lift-off at 05:45:00 Japanese Standard Time, successfully carrying three payloads to orbit. *Below*, pre-mission checkout of the H-I launch vehicle.





Framework for the Future

Japanese industry has developed a formidable reputation for its technological aptitude and flexibility of approach. It is no surprise, therefore, to discover that Japan has far from ignored the commercial potential and scientific interest of space. In the following article *Stephen Byford* looks at the background to the country's mushrooming space industry and provides an overview of Japan's space activities.

MOS-1 (Marine Observation Satellite-1) planned for launch in January 1987.

Japanese involvement in space has grown steadily over the last two decades: Japan's annual space budget now exceeds $620 million. Of this $600 million is allocated to National Space Development Agency (NASDA), $7-8 million to the Institute of Space and Astronautical Science (ISAS) and $7-8 million to other agencies involved in space, such as the Ministry of Transport, the Ministry of Post and Telecommunications, the Telecommunications Satellite Corporation of Japan and the Ministry of Agriculture, Forestry and Fisheries.

Since May 1968 central coordination for Japan's space activities has been provided by the Space Activities Commission (SAC). Its function is to arrive at major policy decisions and to submit proposals to the Prime Minister. In March 1978 it produced the "Outline of Japan's Space Development Policy" which set forth the guiding principles for the nation's space programme for the following 15 years. It also reviews annually the "Space Development Programme".

Space science research is coordinated by ISAS. This body, as part of the Ministry of Education, is responsible for research, development and operation of scientific satellites (including Hinotori, Tenma and Planet A) and of the Mu-series launch vehicles. As an inter-university body, it organises further advanced training for space scientists and engineers.

The practical side of Japan's space effort, however, falls to NASDA. This agency's tasks are entirely peaceful, and are primarily:

1) Research and development of satellites for practical purposes, and of their launch vehicles.
2) Launch operation and tracking of these satellites.
3) Promotion of the technologies for remote sensing.
4) Promotion of space experiments.

Organisations in Japan that wish to use a new satellite must first conduct their own basic research, although they can draw on NASDA's expertise. NASDA takes over the practical task of development only when these initial studies have reached the stage at which development looks feasible.

NASDA's activities in space fall broadly into five categories: Earth observation, communication and broadcasting, space transportation, space experiments, and basic technology.

Earth Observation

The potential offered by satellites for the observation of land and sea is enormous. NASDA has already launched three Geostationary Meteorological Satellites (GMS or Himawari series) and two Ionosphere Sounding Satellites (ISS), and plans include the launch, in January 1987, of a Marine Observation Satellite (MOS-1) and an Earth Resources Satellite (ERS-1) around 1991.

The GMS satellites operate under the Japan Meteorological Agency. The satellites conduct meteorological observations of the Earth in both the visible and infra-red regions of the spectrum. They distribute the resulting images to stations at ground level, together with observational data they have received from buoys, ships and aircraft. Protons radiating from the Sun are also monitored. A fourth GMS is planned for launch around early 1989.

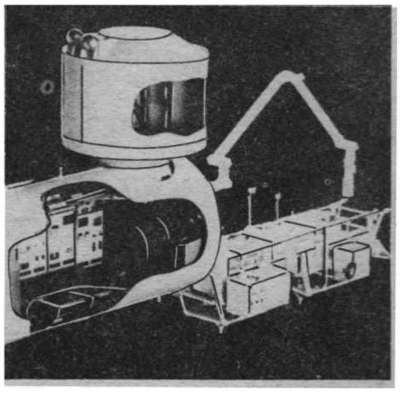
Universities and experimental research institutes will be among those to benefit directly from MOS-1, which will be Japan's first domestic Earth observation satellite; it will be used to detect water vapour in the atmosphere, ocean currents, the surface temperature of the sea, the water content of clouds, the distribution of ice floes and of chlorophyl, and the generation of red tides. Land observations will include the detection of mineral and energy resources, and also of crop types.

Satellite monitoring, in all climatic and lighting conditions, of the natural environment, including natural resources, agriculture, forestry and fisheries, will be made possible by the development of synthetic aperture radar (SAR) observation technology. This will be the purpose of the Earth Resources Satellite (ERS-1), an active sensing satellite currently under development. Its launch, on a two-stage H-I vehicle, is planned in or around 1991. ERS-1 will operate in low Earth orbit for about two years. Trial manufacture of the observation equipment is already underway.

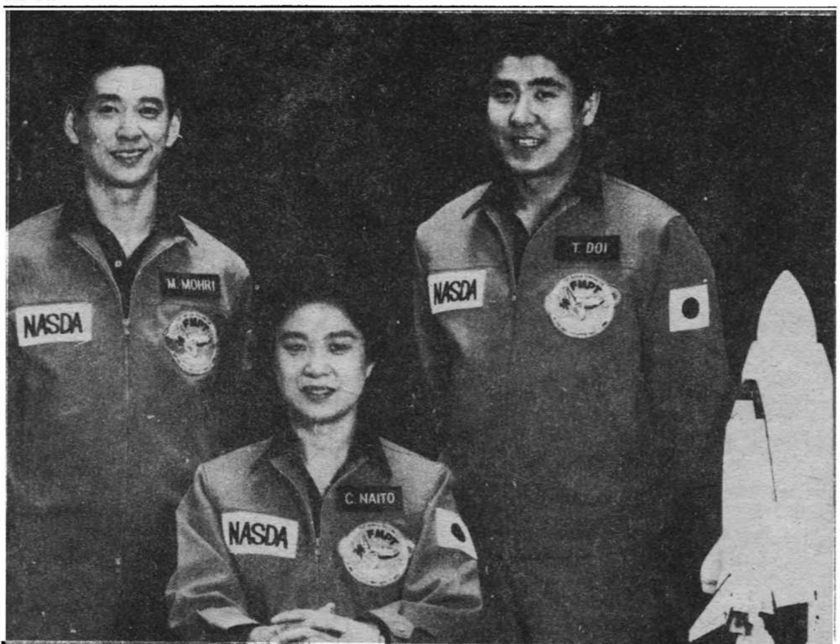
The Experimental Geodetic Payload (EGP) is a passive satellite designed to improve triangulation measurements on the surface of the Earth. This spherical satellite, which was launched on August 13, 1986 is covered with two types of reflector to enable it to reflect simultaneously both sunlight and laser beams shone from the ground. EGP's mission, which is scheduled to last for five years, is being conducted in a circular orbit at a height of 1500 km.

Observational data from remote sensing satellites have been available to Japanese users since January 1979. Information from the Landsat series of satellites has been received and processed by NASDA's Earth Observation Centre, and distributed by the Remote Sensing Technology Centre of Japan (RESTEC). Users include the Ministry of Agriculture, Forestry and Fisheries, the Ministry of Transport, universities, local government authorities, as well as commercial undertakings.

Model of the Japanese Experiment module which will be attached to the International Space Station



JAPAN



Three Japanese payload specialists were selected in the autumn of last year. One of them will fly on a US Space Shuttle/Spacelab mission to conduct experiments in materials processing and life sciences. They are (from left): Dr. M. Mamoru Mohri, Dr. Chiaki Naito and Dr. Takao Doi.

Communications and Broadcasting

The demand in Japan for satellite communications services increases every year – this technology now seems an almost indispensible part of daily life.

The Japanese communications satellite (CS) programme began in 1972, the first experimental CS spacecraft being launched in December 1977 by an American Delta rocket.

This was followed, in 1983, by the launches of two more satellites, CS-2a and CS-2b, each of which was expected to operate in geostationary orbit until 1986-88. These attracted widespread attention because they were the first to make use of the high-capacity K-band frequencies (30-20 GHz).

The CS-2 satellites are used by a number of public service organisations and are managed by the Telecommunications Satellite Corporation of Japan (TSCJ). They enable public communication links with outlying islands and could provide temporary services in special circumstances, for example during natural disasters or other emergencies.

Two larger satellites, CS-3a and CS-3b, are scheduled for launch in 1987 and 1988, each with a projected mission life of more than seven years.

A similar pattern has been followed in Japan's Broadcasting Satellite (BS) programme. As a result of a successful test satellite, BSE ("Yuri"), launched in 1978, two operational spacecraft, BS-2a and BS-2b, have now been launched.

The BS-2 satellites are designed to broadcast two television channels, chiefly for consumers who find it difficult to receive existing services, for example those who live in mountainous areas, outlying islands, and urban environments with tall buildings.

Space Transportation

NASDA's first launch vehicle launched a total of seven satellites between its introduction in 1975 and its last mission in September 1982.

This was the N-I, a three-stage rocket whose first and third stages were based on American Thor Delta rocket technology, as were its three solid propellant boosters. The second stage was, however, the LE-3 liquid propellant engine developed in Japan. The combination could place a payload of about 130 kg into geostationary orbit.

Its successor, the N-II, can put a payload of 350 kg into geostationary orbit, and is still used by NASDA. The first stage is the same as that of the N-I, but now with nine strap-on boosters. The second stage is an upgraded NASA Delta second stage, whilst the third is an enlarged version of that used in the N-I, also American. The N-II employs the Delta Inertial Guidance System. A total of seven satellites have been launched by this vehicle, and another flight is planned before it is superseded by the H-I.

The first test flight of a two-stage version of the H-I launcher carried the Experimental Geodetic Payload (EGP). In early 1987, the full three-stage vehicle will carry a satellite designed primarily to confirm vehicle performance, an Engineering Test Satellite (ETS-V, see later).

The H-1 will soon be NASDA's main launch vehicle, being capable of lifting payloads of around 550 kg into geostationary orbit. In addition, NASDA has plans for an even larger launch vehicle, scheduled for its first launch in about 1991. This will be the H-II, capable of putting payloads of some two tons into geostationary orbit.

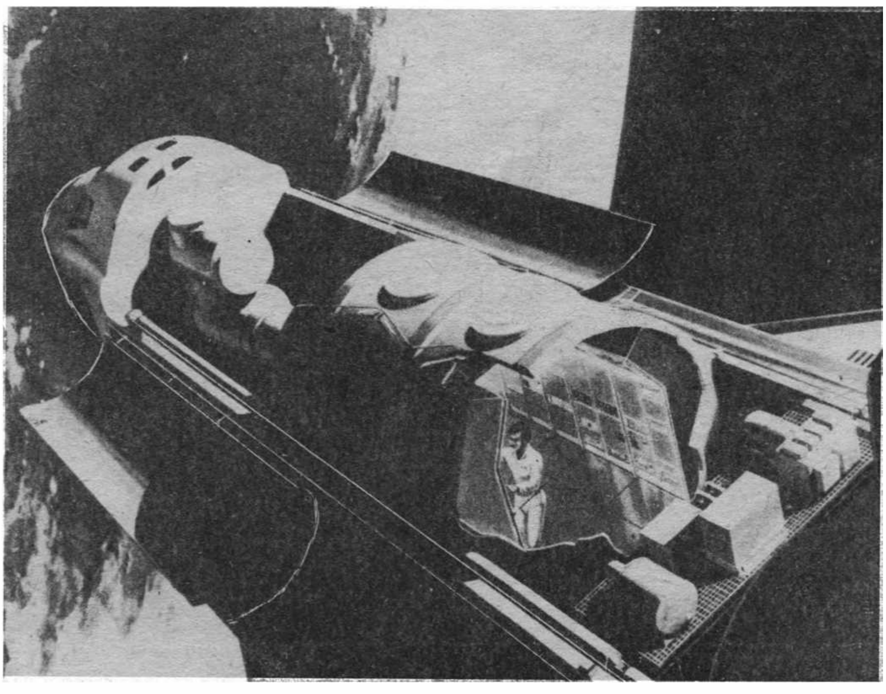
NASDA's launch sites are located at the Tanegashima Space Centre on Tanegashima island, about 1000 km south-west of Tokyo.

Space Experiments

The possible benefits of materials processing and development in space are of great interest to the Japanese.

Since 1980, Japan has carried out preliminary experiments using its own TT-500A rocket, a small two-stage

Artist's concept of the First Material Processing Test (FMPT) aboard the Space Shuttle/Spacelab. FMPT will conduct 30 experiments in materials processing, life science and space-technology



JAPAN

vehicle with a recoverable payload section. This can carry melting experiments and other kinds of tests which can exploit the seven or so minutes of micro-gravity (near weightlessness) available during the free-fall section of the flight.

Successful recoveries have shown that materials of a much higher quality can be produced in space than on the ground.

The next step is an experiment to be performed aboard the European Spacelab carried by NASA's Space Shuttle. The First Material Processing Test (FMPT), as it is called, will consist of some 30 experiments in the fields not only of material processing but also of life science and space technology. The package, requiring three double racks inside Spacelab's pressurised module, will be accompanied by a Japanese payload specialist.

Basic Technology

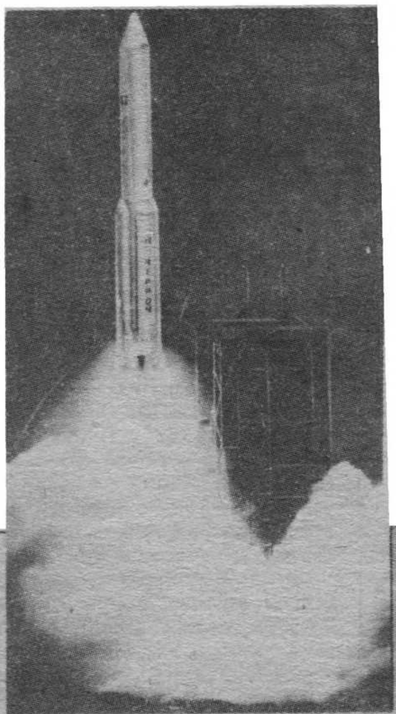
Whilst NASDA readily acknowledges its debt to imported technology, particularly from the United States, it believes that any future space programme covering a broad range of activities will require the firm establishment of Japan's own technology. Its foundations have been greatly strengthened by NASDA's intensive approach to space development.

Research is already underway at NASDA on the basic technologies required for larger satellites, increased vehicle capability, expanding and lightening the satellite bus system, and miniaturising and lightening the mission equipment.

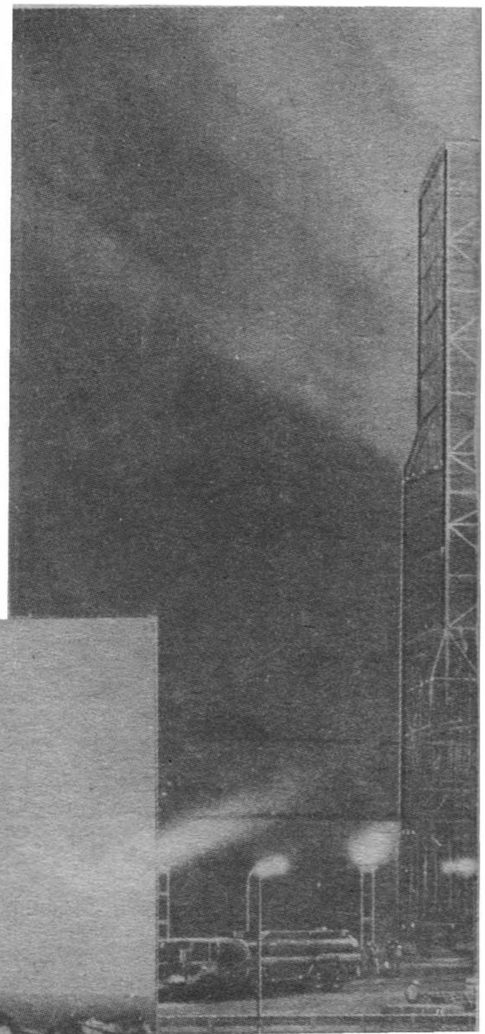
Some of this research has involved the Engineering Test Satellites (ETS). Tests conducted in 1982-83 by ETS-III ("Kiku-4") on basic technologies required for high-power satellites included three-axis attitude controls, solar paddles and active thermal control. ETS-IV ("Kiku-3"), launched in 1981, has continued to be suitable for equipment function tests.

ETS-V is due for launch in the summer of 1987, with a projected mission life of 18 months. Its objectives will include verification of the H-I launch vehicle performance, the establishment of basic technologies required for three-axis stabilised geostationary satellites, the accumulation of key technologies for the next generation of applications satellites, and mobile satellite communications experiments (navigational aid, search and rescue of ships).

Clearly Japan has invested a great deal of money and energy on the development of a thriving space programme. The United Kingdom, perhaps, has much to learn from Japan: in particular, the possibilities that are opened up when space development is given a high national priority.



Artist's impression of the first H-II launch (left) currently planned for 1992.



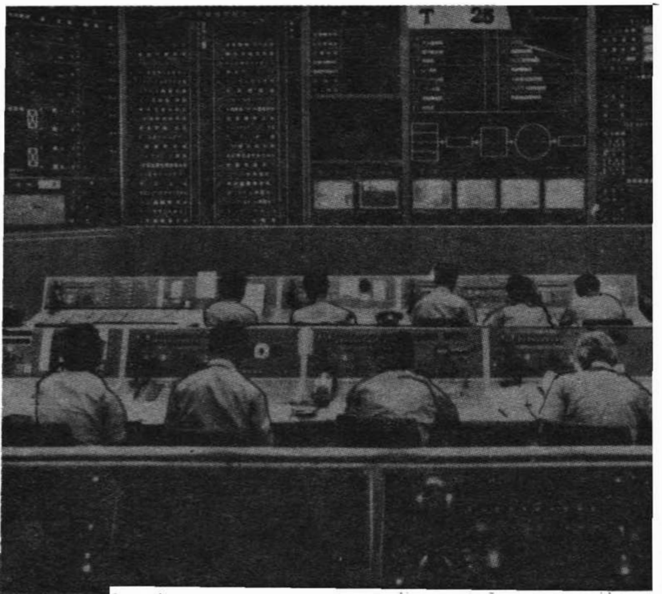
The picturesque Osaki launch site at tne Tanegashima Space Centre, Japan's largest launch complex. Major responsibilities of the centre include assembling and launching satellites, flight safety operation and satellite tracking and control after launch.

H-II ROCKET DEVELOPMENT

Early in 1986 NASDA initiated development of the H-II rocket which will serve as a successor to the N-I, N-II and H-I launch vehicles.

The H-II rocket is designed to serve as NASDA's main workhorse in the 1990s to meet the demand for larger satellite launches at a lower launching cost and still maintain a high degree of reliability.

It will be capable of sending a single two ton class payload or multiple payloads totalling two tons into geostationary orbit. The H-II is a two-stage rocket equipped with two large-scale rocket boosters for thurst augmentation. A new liquid hydrogen/liquid oxygen engine, called the LE-7, is under development for the first stage. The LE-7 is a high performance engine with approximately 100 ton thrust adopting a high-pressure stage-combustion cycle. The LE-5 engine, developed for the H-I, is used in the second stage.



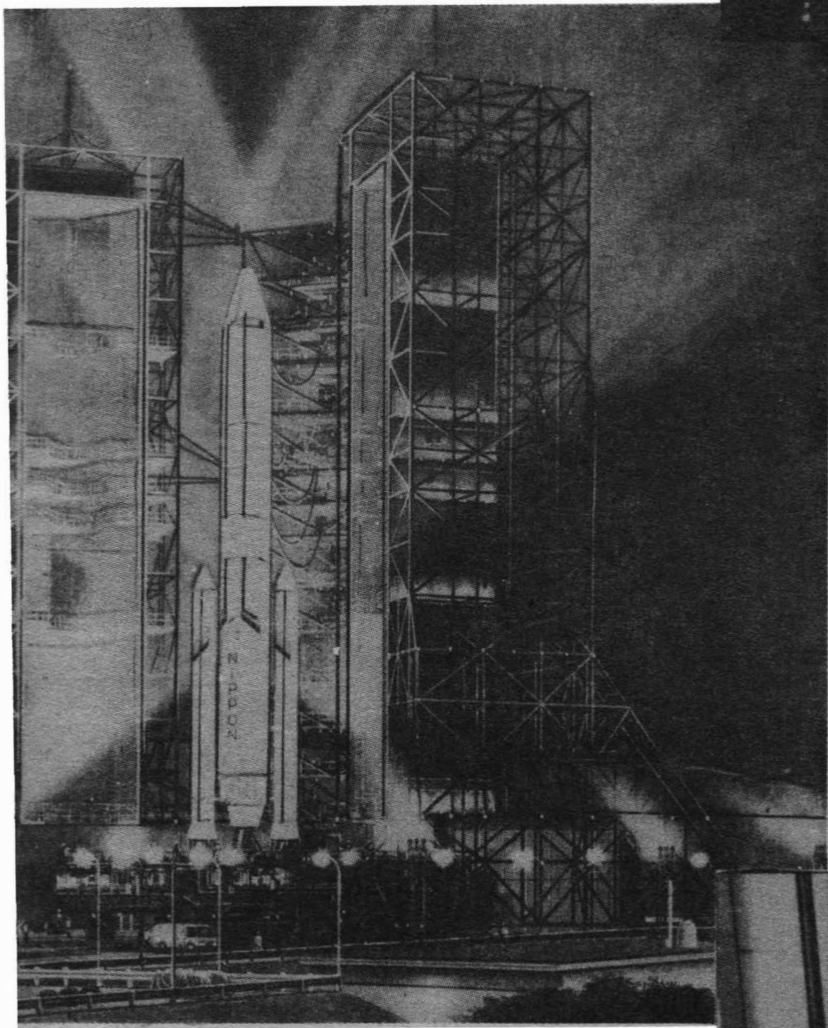
Range Control Centre at the Osaki launch site, Tanegashima.

FIRST MATERIALS PROCESSING TEST

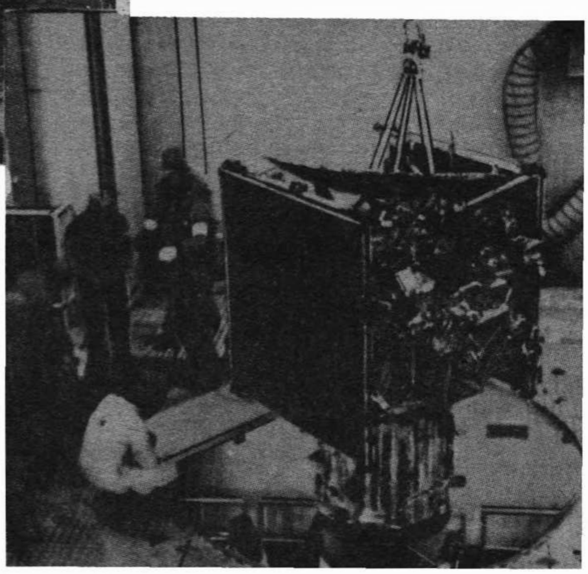
Basis for the First Materials Processing Test (FMPT) goes back to a series of small scale materials processing experiments carried out on TT-500A rockets launched between 1980-1983. The results of studies from these six experiments form the base of the FMPT development programme.

The FMPT will be flown using a Spacelab module aboard the US Space Shuttle following resumption of flights. Spacelab-J/FMPT is currently scheduled for launch about 1990. During this dedicated Japanese Spacelab flight experiments on materials processing, life science and space technology will be carried out using three of the double experiment racks in Spacelab. A Japanese payload specialist will monitor the experiments.

A total of 34 experiments (22 on materials processing and 12 on life sciences) were chosen for the flight from proposals submitted by various research groups, including national research groups, universities and private companies.



A painting of the new H-II booster as it will appear in 1992 before its first launch. The H-II is designed to serve as NASDA's main workhorse throughout the 1990's and meet the demand for the launching of larger satellites at lower costs. It will be capable of sending a single two ton class payload, or multiple payloads totalling two tons, into geostationary orbit. As well as carrying satellites into Earth orbit the H-II will also be capable of launching space probes.



BS-2b, the television broadcasting satellite, which was launched into geostationary orbit on January 23, 1984. The satellite, designed to improve coverage for poor TV reception areas and to develop technology for broadcasting satellites, is seen in the picture at right undergoing final pre-mission checks.

BOOK NOTICES

Cosmic Impact

J.K. Davies, Fourth Estate Publishers Ltd, 113 Westbourne Grove, London W2 4UP. 197 pp, 1986, £9.95.

Evidence of cosmic impacts exists all around us. These are clearly visible on the surface of the Moon and airless planets or even on the surface of the Earth itself, in spite of erosion.

The author is well qualified to write on such a topic. One of the six comets which he discovered missed the Earth by just over 3,000,000 miles, making it one of the closest cometary encounters in recorded history.

Every day, tons of cosmic dust enter the Earth's atmosphere and burn up as meteors. Sometimes, larger stones land as meteorites, occasionally causing minor damage in the process. Earlier in the history of the Solar System, much larger objects – asteroids or the cores of comets several miles across, struck the Earth with such speed that the energy liberated must have produced terrifying physical and biological consequences. The kinetic energy of such objects must have been in excess of a hundred million megatons, roughly equivalent to exploding an atomic warhead on every square mile of the Earth's surface, including its oceans!

The present volume draws together three different themes i.e. why such collisions occur, what happens when they do and what are the likely consquences affecting the Earth's inhabitants. Finally, the 54,000 dollar question is posed – "If another impact was imminent, what could we do?".

Trying to minimise loss of life might turn out to be quite irrelevant – if the resulting ecological effects prove as severe as those postulated in accounting for the extinction of the dinosaurs. In such circumstances, factors totally beyond human control would determine whether man survived or not.

The Cambridge Photographic Atlas of the Planets

G.A. Briggs & F.W. Taylor, Cambridge University Press, the Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU. 1986, 256pp, £7.95.

Men have walked on the Moon during the three decades covered in the book ~~and~~ satellites provided arresting views of our own world so, although exploration of the Solar System is still in its earliest phase, the authors are able to present close-up views of all the planets known to the ancient world, as well as many satellites discovered long afterwards. The result is fascinating, in some cases bizarre and often quite unexpected.

The text accompanying the images and maps in this Atlas (not all the images are made from video data – some use radar and other infrared data) summarises what we have learnt about the planets to date. No attempt is made to provide a detailed historical perspective or to describe individual missions nor, indeed, are there manifold references to the scientific literature, for the simple reason that the atlas is intended for the general reader.

The result is a well-informed presentation on what is currently known about all the worlds of the Solar System, excluding far-distant Pluto, comets etc., compiled by authors who know their subject well. It is an excellent compilation and one bound to please a large readership. The price of the paperback edition is extremely modest for such a substantial and well-illustrated book.

The Wonderful Apparition, The Story of Halley's Comet

R.B. Peterson. Lighthouse. Writer's Guild, Distrib. Univelt, P.O.Box 28130, San Diego, Cal. 92128 USA. 1985, 204pp. Hard cover $18.95.

This is an authorative book on Halley's comet which traces the history of its apparition from the observations of ancient times to that of 1985/6, with the addition of much background information on comets, the nature of Halley's comet and appendices on tracking, positions and magnitudes on its recent return.

In effect, this book merges many of the scientific facts accumulated about a most interesting celestial object with those equally fascinating accounts about men and women who have been associated with its past history. The book describes some of the human story of search and personal sacrifice, of discovery and deception, international competition and of the fear and panic which once accompanied the return of spectacular comets.

It should be noted that the statement on page 159, "with only a single exception, Halley's comet has been observed on every return since 240 BC" should now be up-dated with the discovery of references to the comet's hitherto missing return recorded in the Babylonian tablets (see "Halley's comet and Babylon" ***Spaceflight*** Vol. 27 (9-10), p 360, Sept-Oct. 1985).

Living in Space

Peter Smolders, Airlife Publishing, 7 St. John's Hill, Shrewsbury, England. 1986, 160pp, £10.95.

By 1995 different types of space stations will circle the Earth in a variety of orbits but, in principle, the problems and possibilities in one space station will not be widely different from another.

Sub-titled 'A Handbook for Space Travellers', this book looks forward to the 1990's and tells the story of how there will be space travel for all.

The reader is familiarised with the many different aspects of a possible journey into space, what it would be like and the return to Earth.

There are detailed chapters on operational aspects of the Space Shuttle and the proposed space stations. The book concludes with a look at the possibilities of living eventually in huge space colonies and on other worlds.

The text is enhanced by the lavish use of colour pictures and an excellent series of specially commissioned line-drawings.

The Sun and the Heliosphere in Three Dimensions

Ed. R.G. Marsden, D.Reidel Publishing Co., Spuiboulevard 50, P.O.Box 989, 3300 AZ Dordrecht, The Netherlands. 1986, 525pp, £54.25.

This book not only reviews progress made to date in understanding the three-dimensional structure and dynamics of the heliosphere but also looks ahead to the scientific returns expected from the Ulysses mission. This, a joint ESA/NASA mission, is expected to probe within a few astronomical units of the Sun over the full range of heliographic latitudes and provide *in situ* measurements of the inner heliosphere for the first time, thus adding a new dimension to our understanding of the only stellar plasmasphere to which we have direct access.

The importance of such measurements will be readily appreciated if one considers the market asymmetry in the solar corona (and, by association, the solar wind flow as well) revealed by coronograph images, especially at times of minimum solar activity.

Papers contained in this volume deal with aspects of the corona and its influence on the interplanetary medium, the solar wind, energetic solar particles and galatic cosmic rays, interplanetary dust and interstellar dust – for these also have some bearing on the properties of the heliosphere.

To Utopia and Back

N.H. Horowitz. W.H. Freeman & Co. Ltd., 20 Beaumont Street, Oxford OX1 2NQ. 1986, 168pp, £17.95.

Sub-titled 'The Search for Life in the Solar System', this is a most readable book which surveys both the origin of life itself and the possibility that it may exist elsewhere in the Solar System.

The author begins with three chapters which define what is meant by life and examines theories on its origin, from which one may deduce that the border line between living and non-living matter is not so rigid as one might suppose. Besides a general review of criteria for determining whether planets and satellites are likely to be habitable, the author lucidly explains the chemical and biological conditions necessary for life forms, as we know them, to survive and evolve. The main part of the book goes on to examine present-day knowledge of other worlds, with particular reference to Mars and the Viking missions which, in fact, form the meat of the book.

The author reports at first hand on the microbilogical experiments designed to test for life in the hostile Martian enviroment and relates what the missions disclosed about the composition of the Martian atmosphere, icecaps, dark areas and deserts and, ultimately, ability to support life.

The failure to find life on Mars was a disappointment but, as the author points out, it was also a revelation since Mars offered by far the most promising habitat in the Solar System for extraterrestrial life. In view of this he concludes that 'it is now virtually certain that the Earth is the only life-bearing planet in our region of the Galaxy'.

★ ★ ★

News . . . Society News . . . Society News . . . Society News . . . Society

MEETINGS DIARY

All meetings unless otherwise stated are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ.

20 November 1986 **Symposium**

SPACE TRANSPORTATION: HOTOL

A one-day symposium on the proposed British Aerospace/ Rolls Royce horizontal take off and landing vehicle. Potential authors should contact the Executive Secretary. Registrations details available on request.

26 November 1986, 7-9 p.m. **Lecture**

FUTURE BRITISH SPACE POLICY

by Dr. T. Roberts
Director of Planning and Finance, British National Space Centre.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

2 December 1986, 6-30-9 p.m. **Visit**

SCIENCE MUSEUM – to celebrate opening of new gallery

A special visit by Society members to the Science Museum in South Kensington has been arranged. The programme will provide an opportunity to view the new Space Gallery and see extracts from two vintage space films 'Things to Come (1936) and 'Frau im Mond' (1929).

A contribution of £5.00 will be charged per member to cover the cost of a buffet with wine which will also be provided during the course of the evening.

As the party will be limited in number, advance registration is essential. Forms are available from the Executive Secretary.

28 January 1987, 7-9 p.m. **Film Show**

THE BORDERS OF SPACE (Part 1)

Two film shows will highlight important stages in the development of manned space exploration.

The programme will include the following:

(a) The Legacy of Gemini.
(b) Apollo 15: To the Mountains of the Moon.
(c) Four Rooms, Earth View (Skylab).
(d) STS-2: Post-Flight Press Conference.
(e) STS-5: Post-Flight Press Conference.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

25 February 1987, 7-9 p.m. **Film Show**

THE BORDERS OF SPACE (Part 2)

The second of two film shows continues the survey of important manned space missions.

The programme will include the following:

(a) The Four Days of Gemini 4
(b) The Mission of Apollo-Soyuz 15.
(c) STS-6 Post-Flight Press Conference.
(d) STS-9: Post-Flight Press Conference.
(e) The Space Station.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

LIBRARY

The Society Library will be open to members from 5.30 p.m. to 7 p.m. on the following dates:

26 November 1986
28 January 1987
25 February 1987

Continued from page 384.

Soyuz-TM and Progress Transporters

The Soyuz-TM crew transporter is an advanced version of the Soyuz-T with increased payload capabilities on flights into orbit and back to Earth. Externally it is similar to its predecessor Soyuz-T. Soyuz-TM can communicate with the Earth by a relay satellite, for this it may have a new antenna which can be pointed independently of the orientation of the vehicle.

For docking, Soyuz-TM aligns itself to the axis of the chosen docking port using its new Kurs system. The Mir station is not aligned to the nearing vehicle. At Salyut, both approaching vehicles aligned simultanously towards each other.

The rendezvous radar is attached by a boom to the orbital compartment. This boom may have been shortened or modified to avoid mechanical interference when a Soyuz-TM is docked to a lateral port.

Progress uses the rear axial port of Mir as this is the only port where a rendezvous radar is present to be used during the automatic approach and docking of the tanker. This may also be the only port equipped with a propellant transfer system where fuel can be routed directly to the tanks of Mir situated in the engine compartment at the rear end of the basic station.

Progress is often used to boost the complex to a new orbit. To do so the thrust vector has to go through the centre of mass, thus Progress then has to be docked at one of the two axial ports.

Orbit Operation

The Soviets now have a variety of vehicles to perform space station operations in Earth orbit. The next step will be to dock modules to the Mir base already launched. Analysis of the transport capabilities performed so far in the Salyut programme shows that about 70 t can be orbited per year, sufficient to run a modest build-up programme, including testing and research.

An initial operational configuration will be established after the docking of the large scientific module. This configuration will be similar to the IOC (Initial Operating Capability) configuration of the US station still being planned. The Soviet station would consist of the Mir base, a large scientific module, a Soyuz-TM transporter, and a Progress supply transporter. It will have a mass of 54 t, an internal volume of about 150 m^3 and a power supply of ca. 7-8 kW.

CORRESPONDENCE

Soviet Space Station Plans

Sir, Commenting on David Anderman's article in ***Spaceflight*** (June 1986, p.249) on the Future Capabilities of the Soviet Space Programme, one might suggest that the introduction of a radically new launch system does not necessarily mean the phasing out of an older one. The two systems could operate together for a number of years provided that complementary tasks could be assigned for them.

The significance of the new launch systems can be seen if MIR is actually to be a standard habitat module of the future giant space stations.

The heavy shuttle cargo bay is probably designed to accommodate a MIR station as a standard cargo for use in the construction of a larger space station. The HLLV could put up a 6-8 m diameter third stage of over 100 tons which would carry a large amount of fuel and act as a core vehicle with a multiple docking head for some four MIR substations.

While the main crew of 12-20 cosmonauts would board this giant station using mini-shuttle flights, the Soyuz TM's would still have a role to play providing OTV transportation to similar space stations in other orbits. A Soyuz TM could also stay docked to the orbital complexes for long periods (which the shuttles probably cannot) thereby providing an emergency return-to-Earth capability.

If all this is to be realised in the early 1990's it would be necessary for the HLLV and HLS to be tested at least two years earlier to gain the required experience.

M.Q. HASSAN
Baghdad

Planning for a Lunar Base

Sir, The proposed USA civilian space goals are highly dependent on the outcome of the first Space Station's use. If we are going to the Moon permanently in 2017 (and Mars in 2027) it is very important to size the station so that it becomes that stepping stone/testbed and not an unfilled industrial park.

Instead of asking for and visualising a 26 Shuttle flight station NASA and other partners should ask for support for a space infrastructure stretching to the Moon.

The Moon offers wondrous opportunities for astronomy with its advantages for making higher resolution measurements from less than one arc second to one micro-arc second and detection of energy ranges that are difficult if not impossible to receive on Earth, like 40 mega Hz on the far side.

A total night time gas concentration is only 2×10^5 molecules/cm^3 and the lunar atmosphere's total mass is only 10^4 kg. The largest recorded Moonquake is in the range of Earth's seismic background. The magnetic field from the magnetised rocks range from three to 330 gamma at the lunar surface compared to 30,000 gamma at the Earth's equator. These figures show how advantageous it would be to study charged particles coming in from space on the Moon.

Although it will take a long time to get funding for a lunar base, it is not too early to plan. Serious discussions about the Space Telescope began in 1962.

PER ANDERS HANSSON
London

Advanced Intelligence

Sir, I am writing in reply to E. Coffey's letter in the Sept/Oct 1986 issue of ***Spaceflight***.

The claims of the evolutionary biologists to have solved Fermi's Paradox depend on the following argument. Since the evolution of humanoid intelligence requires a humanoid form, and since the latter is unlikely to evolve on another planet, the galaxy may be teeming with life but devoid of civilisation that we may recognise.

This argument rests upon the critical and fallacious assumption that only humanoid intelligences will develop a technology and be motivated to attempt communication and colonisation of other star systems. In other words, a human-like intelligence is a necessary pre-requisite for the development of a technological civilisation. The possibility that an advanced, but entirely non-human, intelligence might equally achieve this seems such an obvious objection to Coffey's argument that it is perhaps not surprising that CETI scientists have ignored it.

MARTYN J. FOGG
London

Ariane 5 Engine

Sir, I have just read an article about the Boeing/Hughes proposal for the Jarvis launcher which will use a J-2 engine for its second stage.

I did not realise that the production system for this engine was still in existence. This leads me on to the question of why Europe doesn't seek a licence to produce this for its main stage of the Ariane 5 launcher.

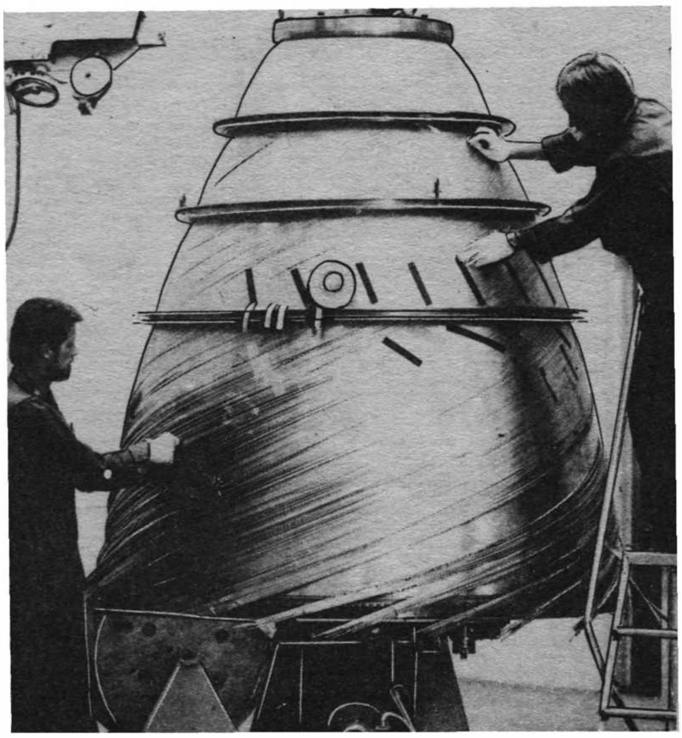
My reason for suggesting this is that the HM60 Vulcain (being developed by Volvo Flygmotor for ESA) and the J-2 have an almost identical thrust, both are open cycle and both use the same LOX/LH fuel. In addition, use of the J-2 would probably enable faster development of the Ariane 5 vehicle.

More importantly, however, it would release the money spent on the development of the Vulcain which could be put into a "Hotol-type" engine research programme. Europe needs a vehicle of this kind as a follow on to the Ariane launcher and I suspect that engine development will dictate the pace of such a programme.

If the United States Trans Atmospheric Vehicle (***Spaceflight*** September/Oct 1985, p.338) is ready by about the year 2000 then at the same time expendable launch vehicles, including Ariane 5, could become obsolete. As Ariane 5 is currently due for its first flight in late 1994 it would only see some six years of operation. This can hardly justify the 2,600 MAU development cost of both engine and launcher.

P.F. HAMILTON,
Rutland, UK

Assembly of tubes for nozzle extension to the Vulcain engines, to be used for the Ariane 5 launcher. *Volvo Flygmotor*



CORRESPONDENCE

Technology: A Lesson From the Past

Sir, I fear that I must take issue with a few points in Mr. Peter Hall's response to my letter in ***Spaceflight*** (June 1986, p 264). This is done not to generate argument but rather because it is vital that the forces at work be understood and that we learn from past experience.

As a first point, he states that he does not agree that an infatuation with technology has driven many policy decisions. Unfortunately, as a player in the NASA arena for many years, I have seen too many decisions made along exactly that line. One may argue whether it was due to technology infatuation or the need to maintain a particular R&D empire but the effect is the same. On one occasion a highly placed NASA planner took me to task for stating that a particular mission could be done without new development. "No one wants to hear that answer" was his summary.

Secondly, I do not say or wish to imply that research on such vehicles as TAV or Hotol should not be done. My point is that first priority must go to maintaining an operational capability. Otherwise we will be forever in the mode of all promise but no capability.

The statement that Space Station was not wanted at the time that Shuttle was begun is simply not true. The entire purpose of the Shuttle was to service a Space Station (in fact, that is the origin of the name) and the two were proposed as a package. The government in essence said to NASA: "We can't afford both. Take your choice." NASA opted to develop the Shuttle. However, without a Space Station to shuttle to it became difficult to justify a Shuttle. In order to justify it NASA added a variety of capabilities not originally intended and finally found itself in the mode of attempting to kill off the expendable vehicles to make sure that there was no competition. Some may take issue with this summary but I believe that a serious study would corroborate the major points.

Finally, the implication that, by pressing on to do missions with existing technology rather than waiting for the future promise, we are somehow risking lives that could be saved by " ... planning and research ..." seems to be rooted in the assumption that our present technology is inadequate. My point is that it is quite adequate and the fact that we have done nothing with that capability for over a decade is much more a failure of vision and leadership than for any other reason.

J.R. FRENCH
California, USA

Exploring Mars – Man Versus Machine

Sir, It is high time that we returned to Mars. Ten years have passed since the Viking landings without a successor mission. This is in spite of the fact that the Viking results did not even rule out the possibility of life at the landing sites, much less over the entire planet.

Indeed, two out of the three biology experiments gave positive results. The prospect for life appeared very good until chemical analysis of the soil found no measurable organic matter. This was a great surprise, since some organics should have been deposited by meteorites, even in the absence of life. However, the chemical analysis was a thousand times less sensitive than the biology experiments.

In the light of the Viking results, there is now a tendency to downgrade the search for life as a Mars mission objective. This is a great mistake. Exobiology should be a primary objective of some missions, and all landers should be sterilised until we know much more about Mars than we do now.

A vast variety of rovers have been proposed. We have tracked vehicles, "beachball" vehicles blown by the Martian winds, and even aircraft. It is hard to say if any of these would be of any great use in looking for life. Much of the mass of a rover would be devoted to making it move leaving less for instruments. Microscopic life might not be obvious at a site and an under-equipped rover could easily miss it.

The best way to search for microscopic life would be to bring a sample back to Earth. Any instrument needed would be available. The investigation would be much more flexible than one using a small automated laboratory millions of miles from the nearest technician. Proposals for a sample return mission require two Space Shuttle launchers to put the spacecraft and its booster into Earth orbit. About a pound of Martian soil could be returned. The cost would be $2 billion or more.

However, this mission poses some problems. First, several months would pass during the return to Earth. Any life present might die in transit. Even if a simulated Martian environment were provided, some vital ingredient could be missing. We might not even recognise the remains of those once-living organisms. The second problem is the chance that Martian microbes could cause disease in man. This is a very remote possibility, but it should be considered.

A manned landing on Mars solves both these problems. First, while material would be carried back to Earth, there would be moderately extensive facilities with trained personnel on the spot. Second, if some microbe did cause disease in man, this would probably be noticed before the expedition returned to Earth.

But a manned landing poses problems of its own. First, contamination of the Martian environment is almost inevitable with astronauts entering and leaving the lander. Second, a manned landing may be very expensive. While many over-estimates ($100 billion) have been made, the cost could still be high. It is hard to say how high, since much of the necessary equipment may be developed for other projects, such as space stations or orbital tugs, reducing the cost of the Mars landing. However, $15 billion is not an unreasonable guess, and may well be too low. This is a major proposition for either the United States or the Soviet Union. A multinational mission would improve matters, but even so can this much money be justified? Much remains to be done

CORRESPONDENCE

in Earth orbit, on the Moon, and on near-Earth asteroids. Not only is this work of scientific importance, but it also has economic and military importance that Mars will not have in the near future. There is nothing to be shipped from Mars that cannot be more easily obtained from the Earth, Moon or near-Earth asteroids.

Only the study of extraterrestrial life can justify an early landing on Mars. We could learn much about life in general if we could look at some organism that did not share a common origin with us. It would be worth almost any price.

We find ourselves in a bind. Only the study of life on Mars would justify a manned landing, while a manned landing has by far the best hope of finding life. We need to re-examine the situation, and design a mission that maximises the chance of finding life while minimising the cost. To do this, we need to get away from the idea of manned missions versus unmanned missions and consider a hybrid approach. Can we get all the advantages of each type and none of the disadvantages?

Not quite, but we can come close. Imagine a sample return mission where the return vehicle docks with a manned spacecraft near Mars. We loose much of the flexibility associated with men on Mars, but we can prevent contamination of Mars. There would be researchers with facilities to examine at least part of the sample while it was still fresh. Any Martian diseases could be detected during the trip home. We also avoid some safety problems if no men land.

Finally, this type of mission would be cheaper than a manned landing. If our manned vehicle goes into orbit about Mars, its mass would be less than half as much when in Earth orbit as a vehicle carrying a manned lander. But why should the manned vehicle go into orbit about Mars? A manned fly-by craft would have only half the launch mass of an orbital one. An orbiter has some advantages. A sample return vehicle can carry more payload into orbit about Mars than to Martian escape velocity. The orbiter could also visit the Martian moons Phobos and Deimos. The moons are interesting both in their own right and as sources of fuel and supplies for future missions. But the fly-by approach is so much cheaper that it would probably be preferred for the first mission. Also along with samples from several parts of Mars a sample from one of the moons could be brought back by the fly-by craft.

A similar approach involving a manned lander was proposed in the early 1970's. A FLEM (Fly-by, Lander Excursion Mode) mission would have the small lander leave the large manned craft some weeks before the fly-by occurred. Only two Saturn V launches would have been needed. While the FLEM mission concept is very interesting, it seems very risky for the lander crew. The launch window for rendezvous with the fly-by craft would be very short, leaving little time to deal with unexpected problems. This is not such an overwhelming concern for an unmanned lander.

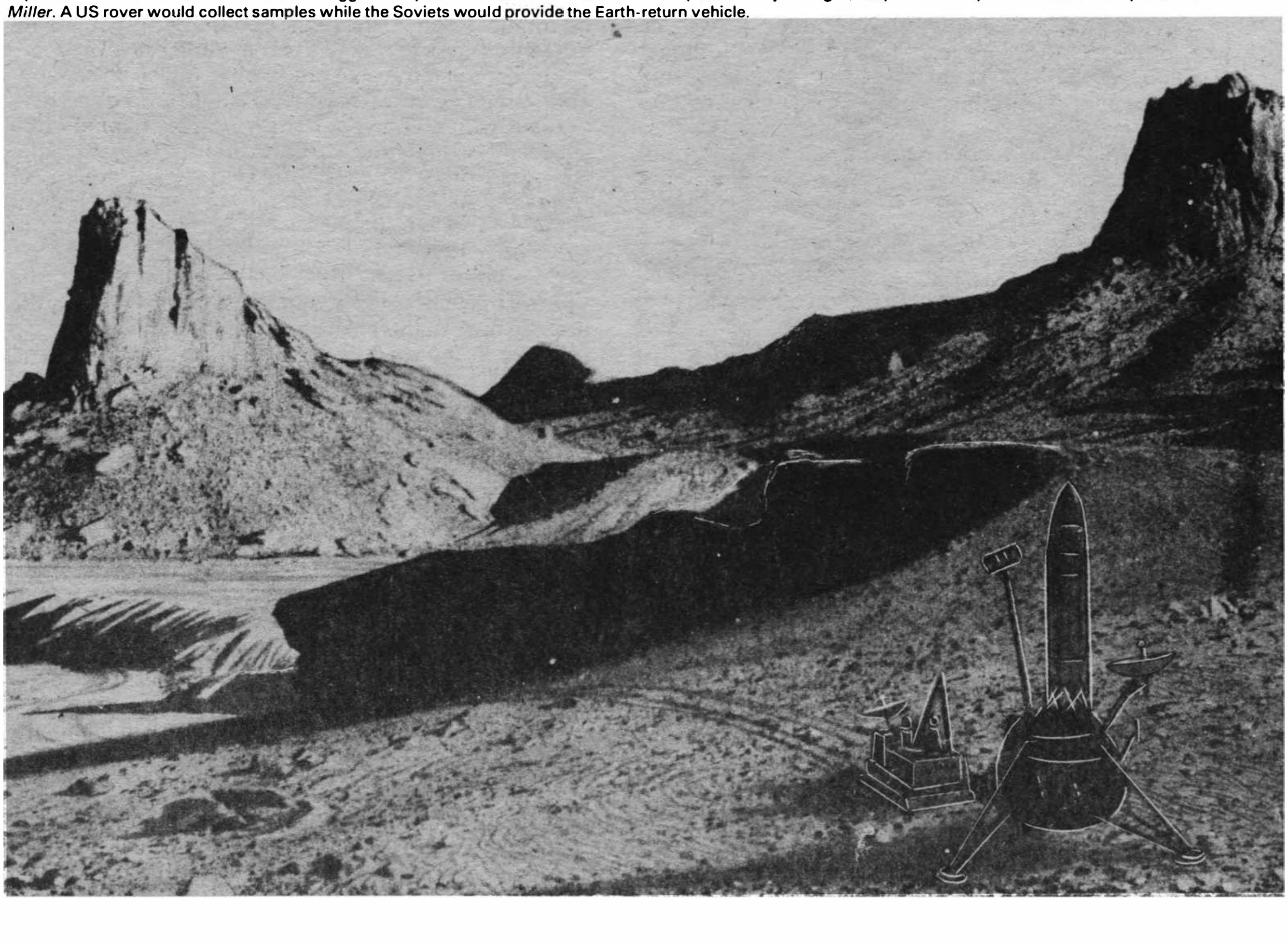
The Soviet Union may be very close to being able to launch a manned fly-by. With the large "Lenin" booster and a Soyuz-Zond type capsule for re-entry, a Salyut space station and its two man crew could fly-by Mars. Unmanned sample return vehicles could be launched separately. This would be a marginal mission, but is still a distinct possibility in the next few years, perhaps in 1992 for the 75th anniversary of the Bolshevik Revolution.

In any case, we should not let ourselves be polarised by the debate over manned versus unmanned missions. We have seen that, at least in this case, a combination of the two is better than either alone. This may be true in other cases as well.

DAVID H. HINSON
North Carolina, USA

REFERENCES
Feinberg, Gerald and Robert Shapiro; *Life Beyond Earth*, William Morrow and Company, 1980.
Oberg, James E *Mission to Mars*, Stackpole, 1982.

A possible US/Soviet mission to Mars as suggested by the US National Commission on Space (see ***Spaceflight***, May 1986) is depicted in this view by artist *Ron Miller*. A US rover would collect samples while the Soviets would provide the Earth-return vehicle.



New Galileo Option

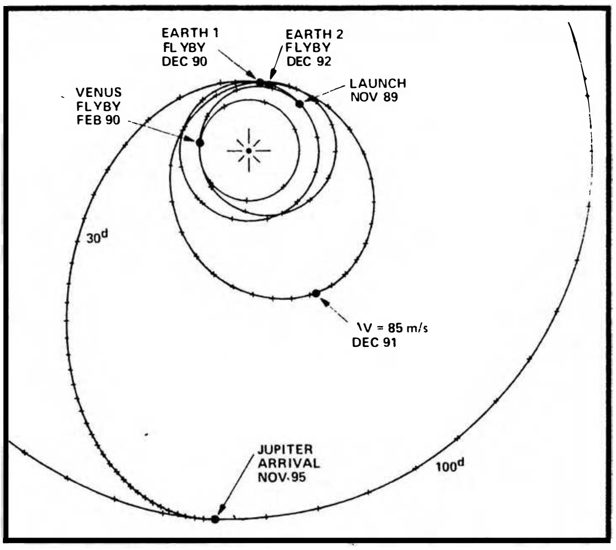
The effect of the January 28 Challenger accident upon the planetary programme continues to unfold. The most extensive redesign has been applied to the Galileo mission to Jupiter: an Orbiter and a Jovian atmospheric probe. The original mission would have begun with a May 1986 launch by a Shuttle/Centaur, a December 1986 flyby of the large asteroid Amphitrite, and a December 1988 arrival at Jupiter to initiate a 20-month exploration of that system.

With the delay of Shuttle flights to 1988 and the cancellation of the Centaur as an upper stage for Shuttle, new schedules and new launch capabilities have had to be devised. It is no longer possible with existing systems to transfer Galileo on a direct flight to Jupiter; gravity-assist techniques will need to be employed to compensate for the energy losses associated with the demise of the Shuttle/Centaur combination.

In last month's column, it was reported that a "split mission" was being considered. This concept would have detached the Probe from the Orbiter and launched them separately. Thus, the requirements upon the launch vehicles would have been less, due to the decrease in mass per spacecraft. However, as the option was studied, it became apparent that difficult cost and schedule problems existed. An additional spacecraft, the Probe carrier, would be required to support the Probe on its trip to Jupiter since the Probe is not a self-sufficient spacecraft. Another factor which mitigated against the split-mission proposal was its use of two launch vehicles, rather than one, to boost Galileo to Jupiter. Launch vehicles are a scarce resource and, in addition, two certainly cost more than one.

Dr. Roger Diehl, a group supervisor in JPL's Mission Design Section, decided to investigate whether there were any gravity-assist options available which would allow Galileo to be sent, with one launch, from the Shuttle with less energetic upper stages than the cancelled Centaur. He first examined the possibilities inherent in the use of a gravity assist from Mars, but no advantages were found to reside in this device. Next, Diehl looked at the possibility of utilising the gravity field of Venus to get to Jupiter. He was initially deterred from pursuing this option because the Galileo spacecraft is not thermally designed to fly closer to the Sun than the orbit of the Earth, and Venus is one-third closer to the Sun than is the Earth. Nevertheless Diehl reasoned that a positive result would be of interest to Galileo management. He was right.

The Galileo spacecraft may proceed to Jupiter along an exotic route which involves a flyby of Venus and two passages by Earth, in order to receive gravitational assists from these planets. *NASA/JPL*



After considerable brainstorming and experimentation, Diehl formulated a trajectory plan which would use a Shuttle launched in Novermber 1989 with a non-Centaur upper stage (candidates exist). The first encounter would be with Venus in February 1990, followed by a December 1990 return to the vicinity of Earth. At this point, the spacecraft would still not have enough energy to go to Jupiter; so, it would be sent upon a two-year delta-VEGA loop about the Sun to return once again to Earth in December 1992, receiving its third and final planetary gravity assist (Venus 1990, Earth 1990, Earth 1992). Arrival at Jupiter would be in November 1995. The option has been labelled "VEEGA" (Venus-Earth-Earth-Gravity-Assist), not to be confused with delta-VEGA options or the two Soviet VEGA missions to Halley's comet earlier this year.

Project Galileo is also prepared to utilise an expendable launch vehicle. This option would employ a Titan/Centaur with a two-year delta-VEGA supplement (the spacecraft would return to Earth almost two years after launch in order to receive a velocity increment, or "delta-V," as a result of this Earth gravity assist, or "EGA"). The spacecraft would arrive at Jupiter in November 1995.

Compared to the 1991 delta-VEGA option the VEEGA trajectory has advantages. It does not require that the propellant tanks on the spacecraft be enlarged to assist in the traverse to Jupiter; this enlargement, necessary for the delta-VEGA option, would be a more difficult task than the thermal modifications required for Diehl's VEEGA approach. Moreover, the VEEGA option would commence the Galileo mission in the nearer term, with a tested launch-vehicle combination (Shuttle with an upper stage has been used to launch communications satellites), rather than a longer term possibility of obtaining the new Titan IV/Centaur G-prime combination.

The principal disadvantage of the VEEGA option is the long cruise time to Jupiter. In a trajectory sense it is just the delta-VEGA path with Venus and Earth encounters added to its front end.

Galileo now has two viable methods for proceeding to Jupiter. It is anticipated that the choice between the 1989 Shuttle-based VEEGA and the 1991 expendable-based delta-VEGA will be made in the next few months.

Space at JPL

Cruising to Neptune

The most important aspect of the Voyager mission to the outer Solar System is its series of encounters with the gas giants: Jupiter (twice in 1979), Saturn (1980 and 1981), Uranus (1986), and Neptune (1989). However, between planetary encounters a significant amount of science and engineering is accomplished by the Voyager flight team.

Voyager 2, having flown by Uranus on January 24, is speeding toward an August 25, 1989 encounter with Neptune. Voyager 1, after its 1980 encounter with Saturn, is continuing to soar above the plane of the Solar System (approximately described by the ecliptic or Earth's orbital plane), at a departure angle of 35 degrees. In 1990 Voyager 1 will be not only beyond the orbits of Neptune and Pluto but also more than 20 AU *above* the ecliptic; for comparison, Uranus is about 20 AU from the Sun. An AU, or Astronomical Unit, is the mean distance from Earth to Sun , about 150 million kilometres.

The Voyager spacecraft are each currently returning about 14 hours per day of fields and particles data, e.g., magnetic field strength and direction and the distant remnants of solar flares.

Remote sensing includes an ongoing programme in ultraviolet astronomy using the onboard ultraviolet spectrometer (UVS). Approximately 100 observations per year are planned. Frequently these observations are coordinated with Earth-based efforts and observations from the International Ultraviolet Explorer (IUE), an Earth-orbiting satellite launched in 1978.

In addition to planning the astronomical portion of the UVS programme, careful consideration must be given to avoid using the scan platform too much. The UVS and three other remote-sensing instruments are located on the gear-driven scan platform. In 1981, one of the gear trains on Voyager 2 seized due to a lubrication problem, and motion of the scan platforms on both Voyager 1 and 2 has been rationed (30 revolutions for each of the two gear trains on Voyager 2 during the Uranus-to-Neptune cruise and 50 revolutions per train on Voyager 1 during this same period of time). Usually, UVS targets are carefully chosen in concert with other uses of the scan platform to minimise the total revolutions. Some UVS astronomy done during the Saturn-to-Uranus cruise was discussed in the June 1984 edition of "Space at JPL".

Another important activity is the continuing calibration of the onboard instruments. The UVS, imaging system (cameras), infrared instrument, and photopolarimeter are guaged by looking at a standard target plate or at stellar targets. Particular attention is paid to the Infrared Radiometer and Imaging Spectrometer (IRIS), because the instrument has been degrading since launch, due to crystallisation of components on the rubber mounting devices for the optics. Confidence is high that the IRIS will function properly at Neptune.

Among the *in situ* instruments, the magnetometer on each spacecraft is calibrated four times per year by performing a so-called mini cruise manoeuvre: four revolutions of the spacecraft about its roll axis and four revolutions about the yaw axis. The adjective "mini" comes from the fact that a cruise manoeuvre was originally designed to employ many more revolutions about each axis – a practice which was later judged to be unnecessary, particularly in view of the extensive ground support it required.

This autumn, engineering tests are being conducted with Voyager 1 to determine whether the Sun can be effectively occulted by the high-gain antenna structure, allowing imaging to be done very close to the Sun. If these tests should prove successful – not too much scattered light from the Sun – it might be possible to image certain dust structures in the inner Solar System which were discovered in 1983 by the Infrared Astronomical Satellite (IRAS). Earlier this year, after the flight team had completed the Uranus encounter, some theoretical analyses were carried out to see if Halley's comet could be imaged from Voyager 1 in May, while the comet was still reasonably bright. However, the analyses showed that the extremely close presence of the Sun, in angular distance, precluded a successful experiment even with the use of the antenna as an occulting device.

Since Voyager 2 lost its primary radio receiver in 1978, it has carried, most of the time, a Backup Mission Load (BML) to carry out a minimal programme of observations should the remaining receiver fail, severing communications from Earth (see the June edition of this column). During Uranus-to-Neptune cruise, the BML to provide protection, labelled BML-5, was uplinked in mid-September and is slimmer than its Saturn-to-Uranus predecessor, BML-4, occupying only about 86 per cent of the onboard computer space that the earlier protective package filled. This allows more

Academy Award

The International Academy of Astronautics has elected Dr. William McLaughlin to full Membership in recognition of his many contributions to planetary science.

We extend our congratulations to him on this occasion and know that the news will be particularly well received by readers of *Spaceflight* who for many years have been kept up-to-date on the work at JPL through his regular monthly reports.

During the last year these reports have covered the Voyager 2 fly-by of Uranus and the consequences of the postponement of the Shuttle programme on forthcoming launches of planetary spacecraft.

● *Dr. McLaughlin is pictured during his presentation at Space '86 (see p.398).*

computer resources to be applied to the collection of data during the normal cruise operations in progress.

The three top scientific priorities built into BML-5 are: obtaining fields and particles measurements five days before and after the Neptune flyby; providing a radio occultation by Neptune for the purpose of measuring the properties of the Neptunian atmosphere; laying a mosaic of images over the large satellite Triton. Although some images of Neptune itself would also be taken, they are not felt to be of as great interest as Triton. One hopes that BML-5 will never be invoked and will simply sleep until it is removed just before the Neptune encounter; but the protection would prove invaluable should the remaining receiver fail, an event with a probability of a few parts out of one hundred.

Also in September, a new computer programme was loaded in the Flight Data Subsystem (one of three types of on-board computers) of Voyager 1 in order to provide for the changing needs of that spacecraft as it recedes further from Earth. In general, lower data-rate options need to be made available since the increasing distance from Earth results in weaker received signals at ground-based antennae.

Work on the Neptune encounter *per se* is moving along rapidly. A change in approach from the Uranus-cruise work plan has started earlier development of Voyager 2 computer loads for the Neptune encounter period (June to October 1989). This plan utilises a lower level of flight team staffing, but for a longer period of time, and constitutes a more efficient application of resources than waiting till later and then rapidly building up the flight team. Of course, some increase in staffing will occur before Neptune, but not with as steep a gradient as for the Uranus encounter.

The Neptune encounter can be subdivided into four phases: Observatory, Far Encounter, Near Encounter, and Post Encounter. To date, the Neptune Observatory Phase has been planned to the level of stringing the desired observations into a time-ordered list: a so-called integrated time line. Observatory Phase features final calibrations of instruments and will also include movies of Neptune, built up from numerous single images, and stroboscopic imaging of the planet to study the evolution of individual features, should they be visible in the atmosphere.

Work is currently in progress on the integrated timeline for the Post Encounter Phase. The other two, more complex phases will be done last.

From time to time we will look in at the Voyager flight team as it continues to prepare for the final planetary encounter of that historic mission.

ICE Spacecraft to Smithsonian Museum

In a ceremony at the Smithsonian Institution's Air and Space Museum in Washington during September, Dr. James Fletcher, the Administrator of NASA, deeded the International Cometary Explorer (ICE) to the museum.

There is one hitch; the spacecraft is still in outer space after having successfully flown through the tail of comet Giacobini-Zinner on September 11 of last year. However, in the year 2014, the ICE spacecraft will return to the vicinity of Earth when, presumably, it can be captured by NASA and placed in the Smithsonian's collection. The National Air and Space Museum has an analogous deeded claim to the Viking 1 Lander on Mars – named the Thomas A. Mutch Memorial Station, after the former NASA Associate Administrator and space scientist who died in 1980 while climbing in the Himalayan mountains. The Museum is charged to retain the Mutch Station plaque, now on display in the main hall, until it can be transported to Mars by American astronauts and affixed to the Lander.

The ceremony of transfer, on the first anniversary of the ICE encounter, served to open a symposium, "Acrobatic Satellites in Deep Space," sponsored by NASA's Goddard Space Flight Center. The symposium took place in the Museum's Albert Einstein Planetarium and addressed the topic of gravity-assist missions, of which ICE is an outstanding example.

Dr. Kathleen Howell, of Purdue University, led off the symposium with the paper "Gymnastic Basics: Understanding Spacecraft Acrobatics." After discussing the fundamentals of the gravity-assist method, she underscored how important the technique has become to the practice of astronautics by listing some of its successes: Mariner 10 to Venus and Mercury, the first interplanetary spacecraft mission to employ a gravity assist; Voyager; Vega, the two Soviet spacecraft that flew past Venus on their way to Halley's comet last year; and, of course, ICE.

Dr. Robert Farquhar, of the Goddard Space Flight Center and Flight Director for the ICE mission, spoke on "The Three Lives of ICE". The first life was its task of monitoring the solar wind at a libration point between Sun and Earth – the task for which it was launched in 1978 as the International Sun Earth Explorer (ISEE-3). The second life was lived as an explorer of the Earth's geomagnetic tail, and, finally, reborn as ICE, it completed the first *in situ* study of a comet. Farquhar hopes that the spacecraft will indeed be able to spend its after life as a resident of the National Air and Space Museum.

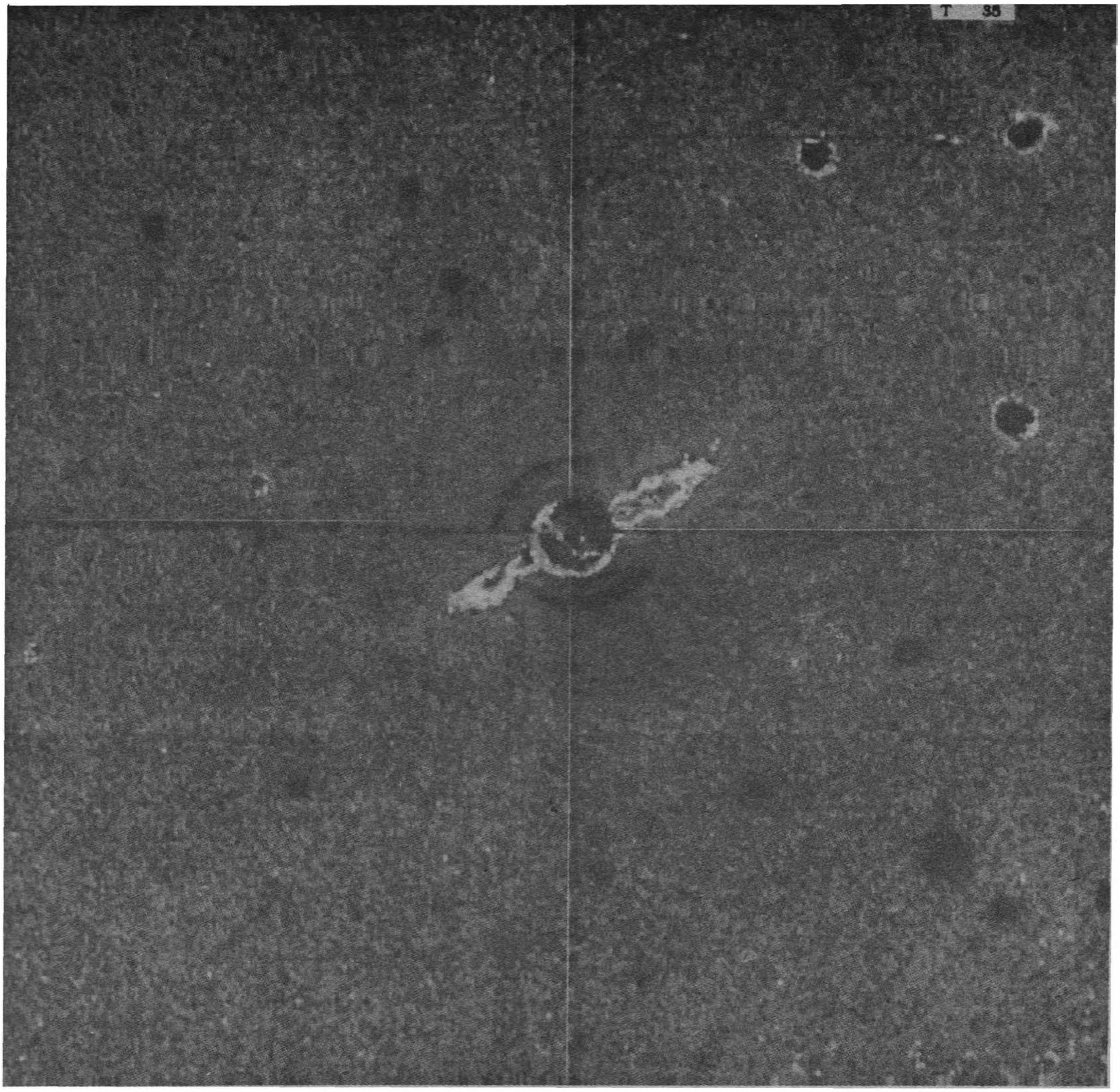
Farquhar also provided interesting glimpses into the "selling" of the cometary mission to the scientific community and to NASA. It was first his desire to redirect the spacecraft to Halley's comet, but analysis by Dr. Joel Smith, of JPL showed that the distance would be too great to support an adequate telecommunications link.

As an afterthought, Farquhar proposed Giacobini-Zinner, half the distance from Earth at intercept, and the rest is history. His actual proposal was made prior to working out the details of the complex gravity-assist process to move the spacecraft from the Earth-Moon system to the comet; some anxious moments were encountered before proof of the viability of the mission was in hand.

Your correspondent presented the third paper, "Voyager and the 'Grand Tour.'" Interested readers can consult the November 1986 issue of *Scientific American* for the substance of this presentation.

Dr. Roger Diehl, of JPL, addressed "The Galileo Mission to Jupiter." Some of the contents of this talk are contained above.

Finally, Chauncey Uphoff spoke on "Solar Sailing," a technique complementary to that of the gravity assist. His historical prologue ascribed to Tsiolkovsky, the Soviet pioneer in astronautics, the first advocacy, in 1924, of the use of solar photons to propel spacecraft. Uphoff went on to describe some future applications of solar sailing, including The World Space Foundation's solar sail project.



The picture of the star ß Pictoris shows what may be another solar system. The disk of material surrounding ß Pictoris extends 60 billion km from the star which is located behind a circular occulting mask in the centre of the picture. This material is probably composed of ices, carbonaceous organic substances and silicates. These are the materials from which the comets, asteroids and planets of our own Solar System are thought to have formed. *JPL*

Planetary Exploration to the Year 2000

In 1980 NASA formed the Solar System Exploration Committee (SSEC) in order to provide a sense of direction, through a plan, for a programme which had often suffered from erratic funding. That plan was published in a May 1983 NASA report, *A Core Program*, which has received widespread distribution.

The core programme features plans for missions to terrestrial (inner) planets, gas-giant (outer) planets, and small bodies (comets and asteroids). It requires no new technology for its implementation and is formulated within severe fiscal constraints. However, there are rewarding missions that could not be included in the original plan due to the dual constraints of technology and dollars. Hence, this year the SSEC has issued a second part of its report, *An Augmented Program*, to recommend challenging missions of the highest scientific value that do require new technology for their completion.

The categories of exploration once again include inner planets, outer planets, and small bodies and have been enlarged to cover utilisation of near-Earth resources and the search for other planetary systems. In addition, technological requirements for these missions are addressed. Only the flavour of this copiously illustrated report of 239 pages can be conveyed here; copies can be purchased from the Superintendent of Documents, U.S. Government Printing Office (Washington, D.C. 20402, U.S.A.).

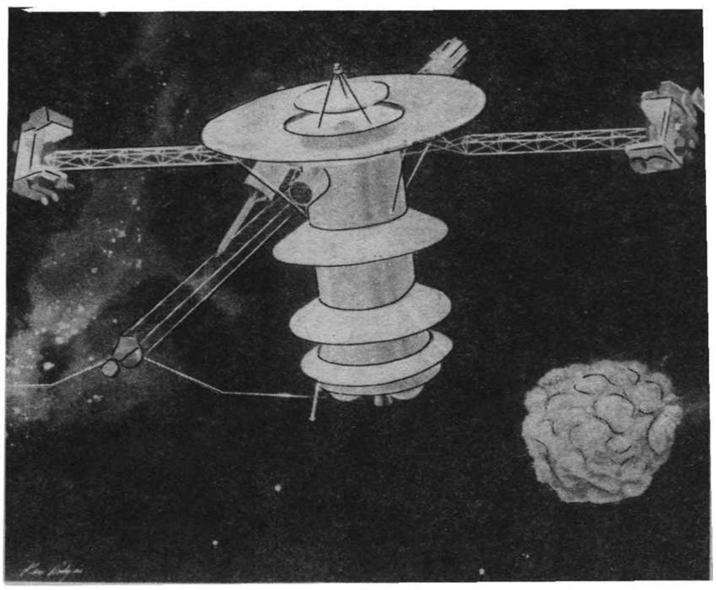
The SSEC report emphasises the key role that sample-return missions can play in gaining an understanding of the Solar System. The advantage of a sample return mission, compared with an *in situ* investigation, is that the full power of sophisticated terrestrial laboratories can be brought to bear upon the analytical tasks.

The structure and crystal patterns of rocks or cometary ices can tell much about the conditions of formation; the mineral content adds further information regarding formation temperature and other physical conditions, while relative isotopic abundances, "atomic memories," indicate when events took place.

The Apollo missions brought back large samples from six lunar sites, and three unmanned Soviet Luna missions added to the picture of our nearest neighbour, the Moon. Two targets envisaged by the SSEC for future sample return missions are Mars and comets, and these missions have been assigned the highest priority in the augmented programme.

A Mars sample-return mission would return about five kilograms of sampled material in an unsterilised state, collected with the aid of a roving vehicle having a range of tens of kilometers. High-resolution images (better than 100 m) taken during the extended portion of the Viking mission will support site selection for the sample return, and further information will be forthcoming from the Mars Observer (1990 launch). The SSEC report describes a mission scenario that begins with a 1996 launch, followed by a 300-day trip to Mars with 400 days on the Martian surface. Counting the return to Earth, the mission would span 34 months.

The Comet Nucleus Sample Return (CNSR) mission would provide a follow-on to the Comet Rendezvous Asteroid Flyby mission, which plans to rendezvous with a comet and, possibly, fire a penetrator into the nucleus. One focus of the study of a nuclear sample would be to try to determine whether small particles in the sample were formed in the solar nebula or at an earlier time in the interstellar medium. It is an exciting prospect to contemplate having material at hand that might predate the origin of the Solar System itself. The CNSR mission could be enhanced by placing a long-term monitoring station on the surface of the cometary nucleus.



JPL Spacecraft proposed for CRAF mission

The exploration of the outer Solar System to date has been done by the two Voyager and two Pioneer spacecraft. The Galileo mission to Jupiter is funded but beset by launch-vehicle problems as described earlier. The 1983 SSEC report recommended four core-programme missions to the outer Solar System: Titan flyby/probe, Saturn Orbiter, Saturn Probe and Uranus flyby/probe. These missions need not be done separately – combined efforts are possible, such as the proposed Cassini mission which features a Saturn Orbiter and a Titan Probe. Only the time constraint on the extent of the report (year 2000) prevented the addition of a Neptune flyby/probe and a Pluto flyby to the core list of the SSEC programme.

The existing data base is not currently adequate for in-depth planning of an augmented programme for the outer Solar System, but the new SSEC report has identified Jupiter, its volcanically active moon Io, the rings of Saturn, Titan, and Neptune's large satellite Triton as candidates for further exploration. The latter body will be examined from close range by Voyager 2 in August 1989. There is speculation that Triton may be covered by oceans of liquid nitrogen. If this proves to be true, a boat-like lander could be used for exploration.

The recent US commitment to building a Space Station has made the exploration of the near-Earth environment even more feasible since the issuance of the first SSEC report. The augmented programme foresees the exploitation of lunar and asteroidal resources. An interesting early use of lunar material might be to serve as the basis for large structures placed so as to shield the Space Station from man-made orbital debris; almost 6000 artificial objects are currently tracked in Earth orbit, and 72 per cent of these are classified as debris. As the number of these objects grows, it may become necessary to build shields for orbital facilities. The cost of bringing material from the Moon to low-Earth orbit is less than bringing material from Earth.

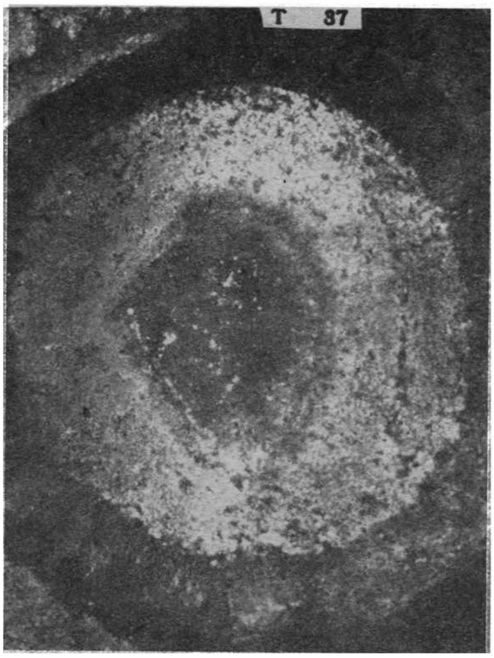
For a long time, astronomers have attempted to demonstrate the presence of small, invisible companions to nearby stars by careful measurements of the trajectories of some of these stars. Some results have suggested the existence of these possibly planet-like objects. In 1983 the Infrared Astronomical Satellite (IRAS) detected disks of material in orbit about several stars, including Vega and Beta Pictoris. The SSEC report recommends that NASA continue the search for planetary systems using a variety of Earth-based and space-based techniques.

The final chapter of the SSEC report investigates the technological tools required to carry out the proposed missions. None of the missions in the augmented programme can be carried out with existing technology – a situation which is healthy because it promotes the historic role of space exploration as an avenue to technological development. Desirable new technologies include: solar-electric/nuclear-electric propulsion systems, aerocapture techniques, automated roving vehicles, and automated remote-sampling methods.

The vision of the future presented by the augmented programme is a compelling one, and the roadmap laid out by the SSEC is a great service to the space community, bringing order to a previously jumbled situation. 'It shows the power of a thorough planning process. One can only hope that the will and resources to carry out significant portions of the core and augmented programmes will be found.

COSMIC COLLISIONS WITH THE EARTH

by Dr. John K. Davies*



Wolf Creek crater seen from above

One of the major surprises revealed by unmanned planetary exploration has been the discovery that almost all the planets and moons in the Solar System have impact craters. Only in very few cases, such as Jupiter's volcanic satellite Io, are geological processes fast enough to smooth over craters almost as quickly as they are formed. Most of the large impacts, such as those which formed the lunar basins, occurred very early in the history of the Solar System during the process of planet building, but it is clear that quite large impacts still occur occasionally as comets and Apollo asteroids sweep in towards the Sun, cutting across the orbits of the planets. Using crater counts geologists estimate that an object large enough to form a crater 20 km or more in diameter strikes the Earth about every two million years. This estimate is confirmed by astronomers from the frequency of Earth approaching asteroids and comets.

First Findings

Of course, the existence of a few terrestrial impact features has been known for some time, for example the famous Meteor Crater in Arizona was discovered in the 1870's as American settlers headed westwards during the last century. Originally called "Coon Butte" or "Coon Mountain", the apparently circular feature with its raised rim was visible for many miles across the flat landscape and was originally believed to be the remains of an extinct volcano. The discovery of pieces of iron around the crater attracted the interest of prospectors, who took samples for analysis, and eventually Dr. A. E. Foote, a mineralogist and meteorite collector from Philadelphia, acquired one of these fragments. Realising that the material was meteoritic iron, he travelled to Arizona in 1891 and collected over a hundred meteorites from the area surrounding the crater. Despite his finds, Foote seems to have shied away from suggesting that the crater itself was formed by a meteorite, perhaps because such a proposal was so contrary to the established geological thinking of the day.

Then in 1902, the existence of the crater came to the attention of Daniel Moreau Barringer, a mining engineer from Philadelphia. Barringer set out to examine Coon Butte and was sufficiently interested by what he saw to negotiate the mining rights to the land in which the crater lay. Forming the Standard Iron Company to raise the necessary capital, Barringer studied the crater intensively for many years and confirmed that it was due to the fall of a huge iron meteorite which he believed still lay buried beneath the surface. Examination of the small fragments of iron found around the crater showed that they contained traces of nickel, platinum and even small diamonds so it seemed that the main body of the meteorite would be a considerable prize.

Barringer's company spent considerable time and money drilling boreholes in search of the meteorite, but despite their efforts, and the outlay of around a quarter of a million dollars, they never did find the metal rich core they were seeking. Despite this failure Barringer's work is now recognised as being of great importance and the crater is now known as the Barringer Meteor Crater.

Once the meteoritic nature of the Barringer Crater was established it was not long before the site of a second impact was identified near the town of Odessa in Texas. The Odessa crater was discovered in 1921 and is much smaller than the Barringer Crater, being only about 170 metres in diameter, a few metres deep and surrounded by a rim that rises less than a metre above the ground. Excavations of the crater in 1939 revealed that the original floor was about 27 metres below ground level and that three smaller craters, now completely obliterated, had once existed nearby. The erosion of the outer rim to its present level, combined with the filling of the crater over the years, clearly show that the Odessa crater is very old, a supposition confirmed by the discovery of a fossil horse, of a type now extinct, during the excavations.

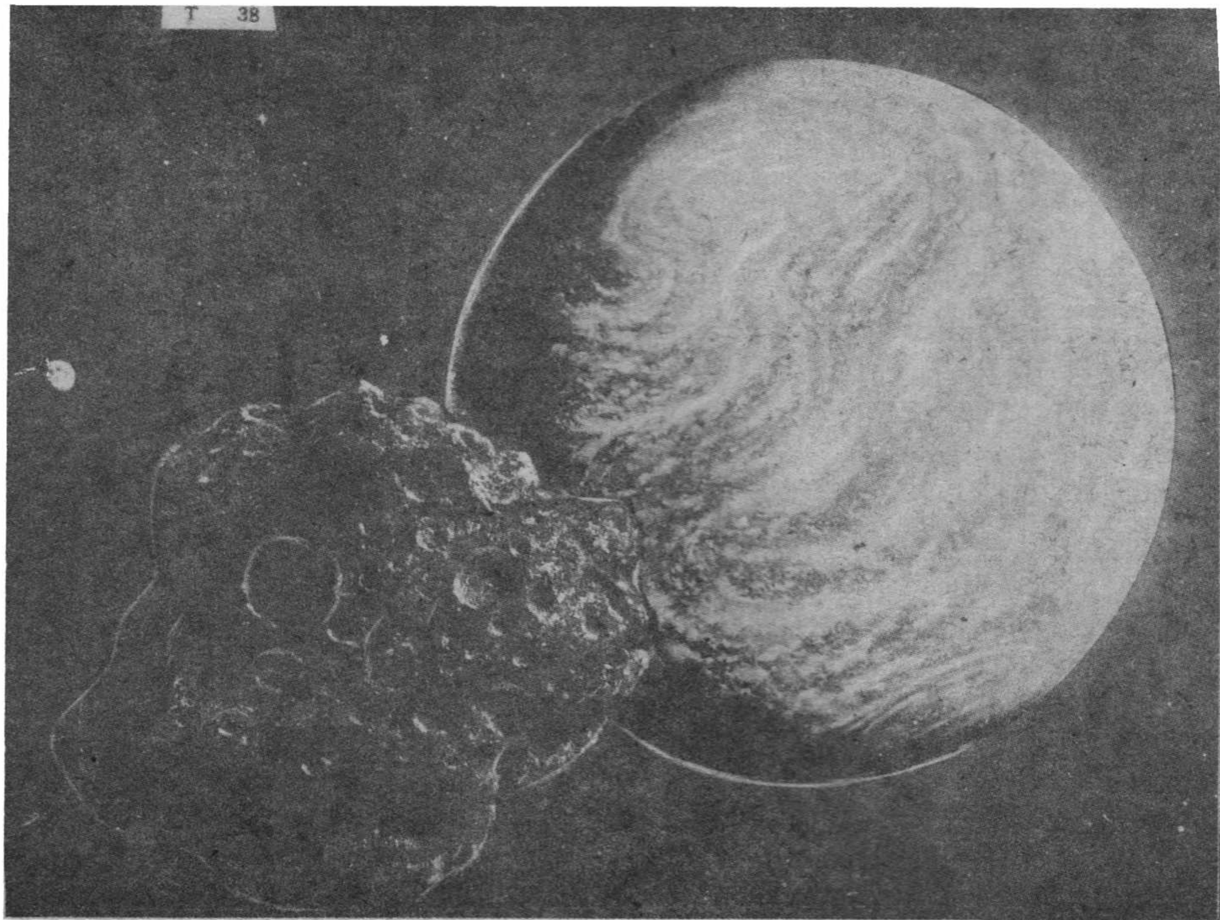
Fragmentation

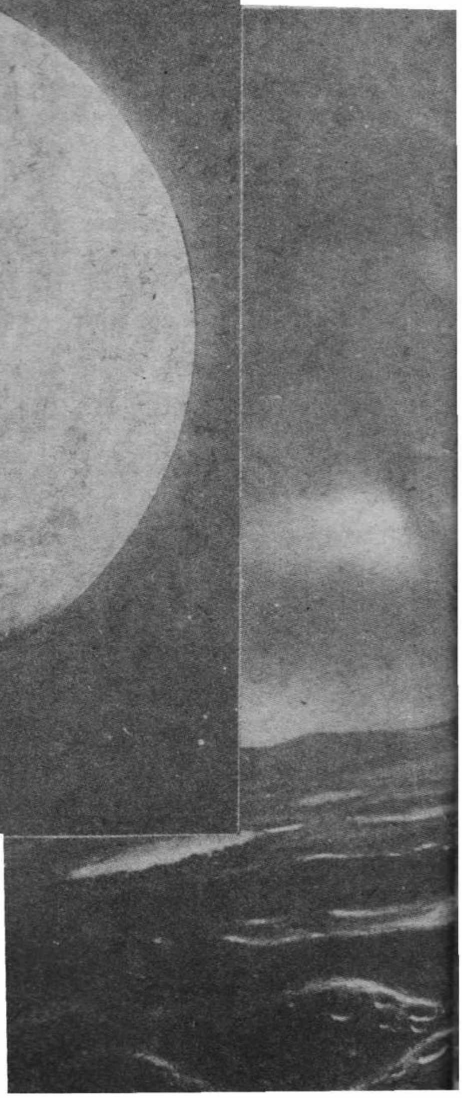
Like the Arizona meteor, the object which formed the Odessa crater appears to have had a metallic composition since many iron meteorites have been found in the vicinity. The total amount of material recovered from the main and three subsidiary craters amounted to about ten tonnes, more than half of this being recovered from the largest of the three satellite craters. From the sizes of the craters, and the distribution of the recovered meteorites, it appears that the original object fragmented at low altitude into four main pieces. The largest of these exploded when it struck the ground, disintegrating and ejecting small fragments which fell in the crater walls and on the surrounding countryside. The three other fragments had insufficient energy to explode on impact and simply buried themselves in the ground, causing mechanical damage but no explosion. It is these fragments which made up the bulk of the material recovered from around the site.

A further decade passed before a third crater was discovered, 13 kilometres WSW of the Henbury Cattle Station in Australia, just a few hours

The almost vanished Brent crater in Canada 3.8 km across and over 400 million years old.
Canadian Dept of Energy, Mines and Earth Resources.

*This article is based on extracts from 'Cosmic Impact' by John Davies and appears by permission of Fourth Estate Publishers, 113 Westbourne Grove, London, W24UP.





An Apollo Asteroid approaches the Earth *David A. Hardy*

drive from Alice Springs. A group of craters was found here in May 1931 by A. R. Alderman who was following up reports made to another meteorite researcher that iron fragments had been found in the Henbury area. Alderman was only able to make a brief survey of the site, during which he recorded a total of 13 craters and collected a number of meteorites, but subsequent expenditions explored the area more thoroughly.

Elliptical Pattern

The Henbury craters lie in an elliptical pattern which covers a total area of about one and a quarter square kilometres. The largest crater is highly elongated, being 220 metres long, 100 metres wide and about 10-15 metres deep. This unusual shape is the result of two craters forming so close together that they had a common wall. Over the passage of time the wall has been eroded away allowing the two craters to merge into one. Two other craters, 73 and 53 metres in diameter, lie very close to the main depression, while the remainder are all less than 50 metres across and lie to the south and west. This distribution reveals two facts about the impact which formed the crater field. Firstly, the incoming projectile must have fragmented at fairly low altitude, allowing all the meteorites to fall so close together. Secondly, since the heaviest fragments of a disintegrating meteorite are slowed less by atmospheric drag and thus travel furthest, the object must have been moving from south-west to north-east as it entered the lower atmosphere and exploded.

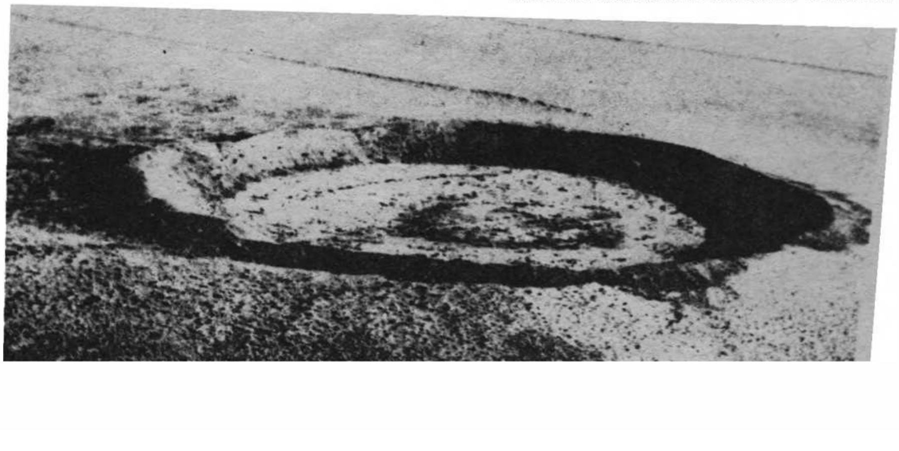
The precise age of the Henbury craters is uncertain, but they were probably formed within the last 5000 years and in this respect it is interesting to note that local legends recall that the craters were born in a fiery explosion. One of the Aboriginal names for the region which includes the craters is "sun walk fire devil rock". This name, and the legends, may indicate that the formation of the craters was actually witnessed by some of the early inhabitants of the region.

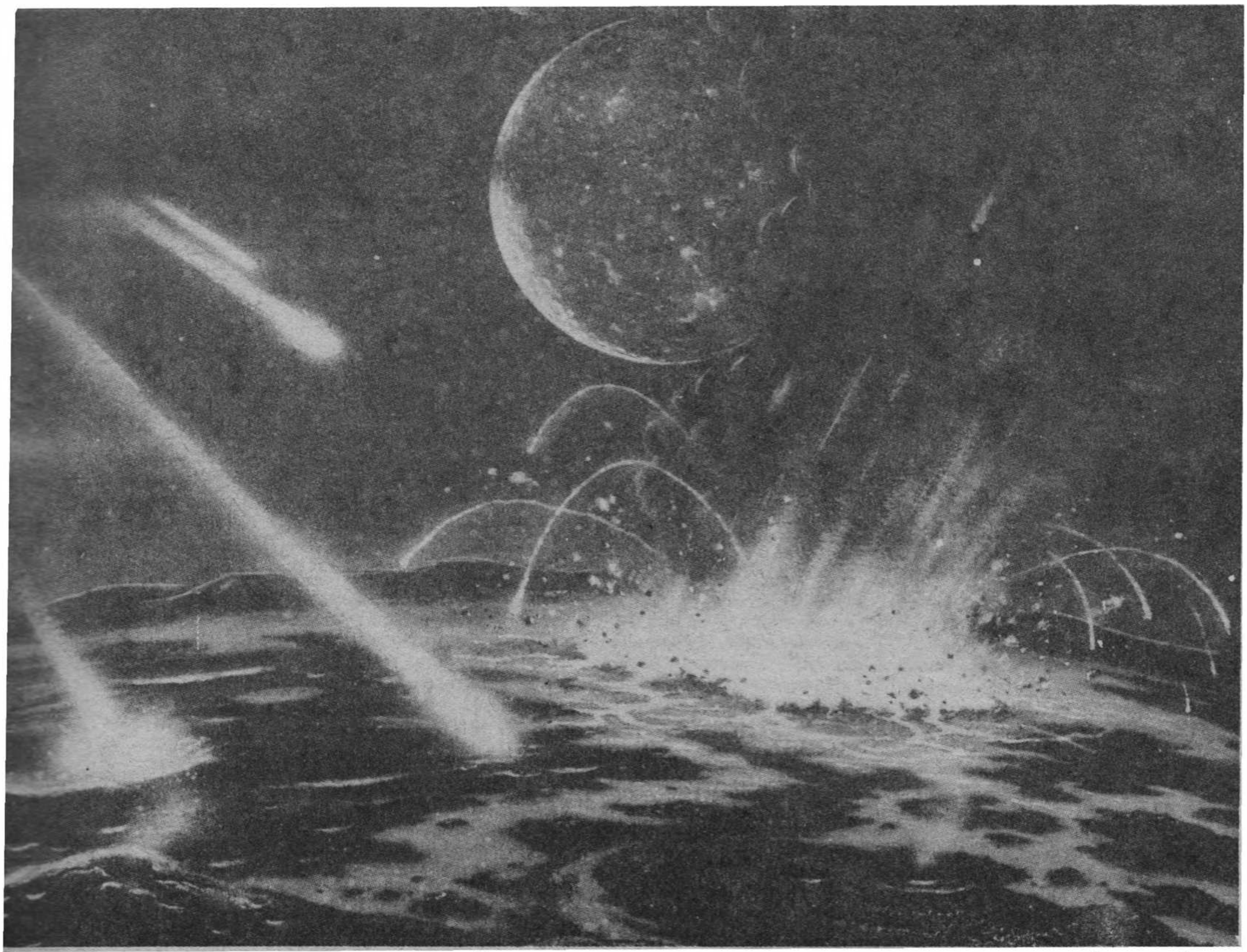
Following the discovery of the Henbury craters a number of other impact sites were identified in the nineteen-thirties including a group of seven craters at Kaalijarv, on the island of Saarema, Estonia and the 175 metre diameter Boxhole crater in Australia. Several more discoveries were made, often from aerial photographs, in the years after the second world war and by the early 1950's the total had risen to 11 confirmed, plus about the same number of suspected, craters.

Spectacular Success

Towards the end of the 1950's a search was mounted for possible impact structures in Canada, using the results of an extensive programme of aerial photography. This was spectacularly successful and a number of new craters were identified, including the 200 million year old Manicouagan lake in the province of Quebec. Manicouagan lake is a doughnut-shaped body of water, 70 kilometres across, with a broad circular peak of rock rising from the centre. When viewed from

The Wolf Creek crater, 0.8 km across, in Australia





Earth under bombardment from space during its formation

David A. Hardy

above, especially from the vantage point of space, its resemblence to a large lunar crater with a central peak is remarkable.

Another Canadian feature recognised as the result of impact cratering were the two Clearwater Lakes found to the north of Quebec. The Clearwater Lakes consist of two circular bodies of water, about 20 and 30 kilometres in diameter, which almost overlap. The larger of the two, which lies to the west of the pair, has an almost circular ring of islands within it and this circle is concentric with the outline of the lake itself. At the centre of the lake lie another group of small islands which mark the top of a subdued central peak. The eastern lake, which is smaller, is deeper and although it too has a central peak this does not break the surface of the water. Like Manicouagan Lake, the Clearwater Lakes resemble lunar craters and are clearly of impact origin. Detailed investigation of the structure has confirmed that the present shorelines of the lakes mark the edge of the original crater rims and has traced disturbances in the underlying rock well beyond the rims.

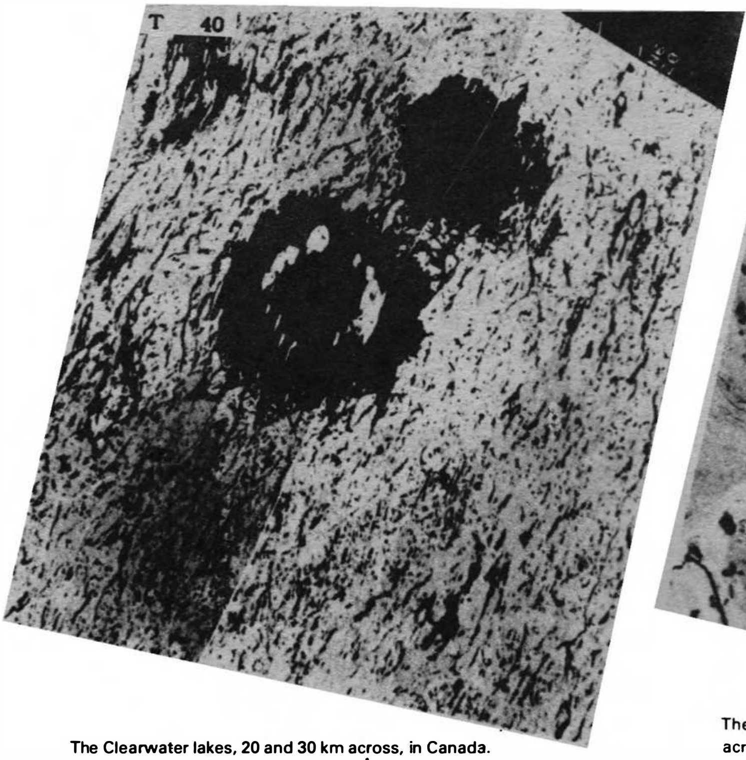
The location of two craters so close together is of course probably not a coincidence, especially since they both appear to be about 290 million years old. The impacting object, probably an asteroid a few kilometres in diameter, was apparently split in two by gravitational stresses as it approached and the two fragments only had time to separate slightly before they struck the Earth and exploded.

The discovery of these large and very ancient craters showed that astroblemes, as impact features are sometimes known, could be much bigger than the one or two kilometre structures identified before 1950 and that they might exert considerable influence on the local landscape. The success of the Canadian work encouraged other scientists to search for impact craters and by 1972 a total of 48 probable craters were listed. This list of astroblemes has continued to grow, in 1979 the number of probable craters had increased to 78 and by 1982 91 were known. The dozen or so craters associated with meteorites (Table 1) take the total number beyond the hundred mark.

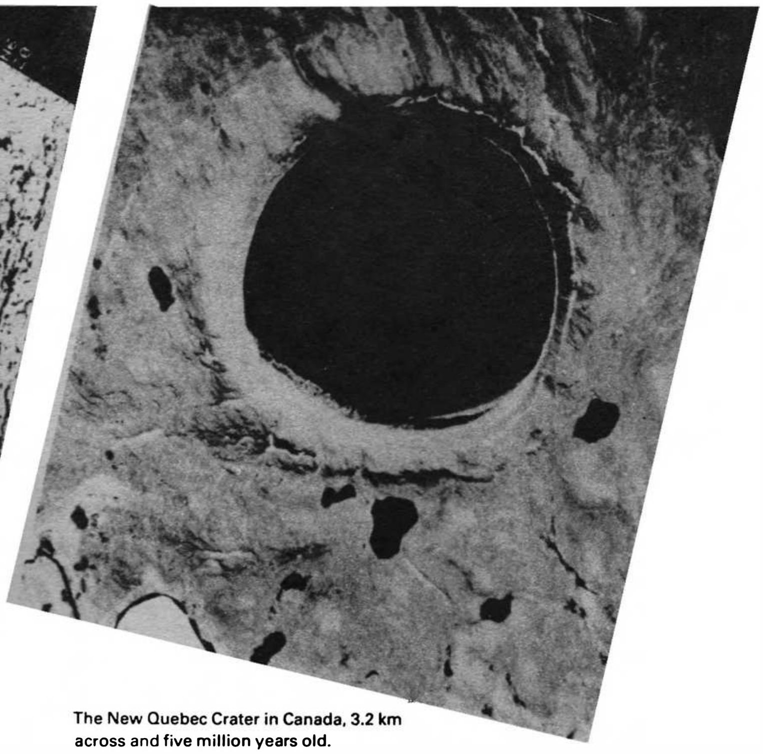
Ancient Structures

The two oldest impact structures yet discovered on the Earth, are also the largest. They are the Sudbury basin, in Ontario, Canada and the Vredefort dome in South Africa. Both are about 140 kilometres across and date back almost 2000 million years. Over millions of years the Sudbury basin has been distorted by geological movements unrelated to its formation and has also been partly filled by large volumes of igneous rock, which flowed up from below the crust and then solidified. Whether this filling was triggered by the impact or was due to quite unrelated subsequent activity is not yet fully understood.

The Sudbury basin is currently the source of much of the world's nickel, and this productivity may be due to changes in the local rocks caused, at least in part, by the original impact. The nature of the Vredefort dome as an impact structure, suggested by its central uplift and surrounding depression, has been confirmed by the presence and orientation of shatter cones (unusual structures in the underlying rock), and by the discovery of coesite (a



The Clearwater lakes, 20 and 30 km across, in Canada.



The New Quebec Crater in Canada, 3.2 km across and five million years old.

type of quartz which is only formed under conditions of very high temperatures and pressures) in the locality.

Not all the Earth's craters are as old as these examples. The 10 kilometre Lake Bosuntwi, which is the sacred lake of the Ashanti tribe of Ghana, was confirmed as an impact structure in the early 1960's by the discovery of coesite nearby. This crater is believed to be just over one million years old and is probably associated with the nearby Ivory Coast tektite field (tektites are unusual stones thought to be material splashed out during the formation of a crater which then solidified in flight). A similar age has been found for a seven kilometre crater at Zhamanshin to the North of the Aral Sea in Kazakhstan, USSR. This crater also appears to be connected to a nearby tektite field. Another large crater, 19 kilometres in diameter, which contains Lake Elgygytgyn and is located near the Arctic coast of Eastern Siberia is believed to date back about three and a half million years.

The discovery of these craters, and the understanding of the manner in which their sizes and ages vary is of great interest because, in principle, it should allow the rate at which comets and asteroids strike the Earth to be calculated. Unfortunately, the true crater distribution over the Earth is extremely difficult to establish since, although the age of an individual crater can be determined by detailed geological analysis, the number of craters on our planet today reflects not only the rate of formation, but also the way in which craters are preserved once they are formed.

Table 1 Some craters at which meteorites have been found.

Name	*Location*	*Number of Craters*	*Diameter of Largest Crater (metres)*
Barringer Crater	Arizona, USA	1	1200
Boxhole	Northern Territorry, Australia	1	175
Campo del Cielo	Argentina	20	90
Dalgaranga	Western Australia	1	21
Haviland	Kansas, USA	1	11
Henbury	Northern Territory Australia	13	150
Kaalijarv	Estonian SSR, USSR	7	110
Moraska	Poland	7	100
Odessa	Texas, USA	4	168
Sikhote-Alin	Primorya Territory USSR	122	26
Veevers	Western Australia	1	80
Wabar	Saudi Arabia	2	97
Wolf Creek	Western Australia	1	853

Cratering Rates

Using the number of craters larger than 20 kilometres across, i.e. those which survive for long periods, on the stable North American and European continental shields geologists have tried to calculate the cratering rate in these areas over the last 350 million years or so. The result for the two areas are then combined to try and improve the accuracy of the analysis, because a total of only 16 craters is involved and such small numbers can lead to large statistical uncertainties in the results. Using these crater counts geologists estimate that an object large enough to form a crater 20 kilometres or more in diameter strikes the Earth about every two million years, an estimate which is close to the collision rate deduced by astronomers interested in Earth approaching asteroids and comets.

Since the estimates of collision rates made by astronomers depend on the total population of asteroids and comets, neither of which is known with any certainty, and those made by geologists depend on using the results of less than 20 craters spread across only 11 per cent of the Earth's surface the fact that both figures almost agree is very encouraging and implies that most craters were probably formed by normal Earth crossing asteroids. These objects are prime targets for unmanned exploration using Mariner Mk 2 or planetary observer spacecraft and one day astronauts may be able to visit them and harness their resources for space colonies on 'The High Frontier'. Until then we can only wait and hope that the next catastrophic impact is still thousands of years away

DECEMBER 1986 £1.25 $3.00

Spaceflight

The International Magazine of Space and Astronautics

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-12 Внеочередной
(спейсфлайт)

ВНИМАНИЮ ПОДПИСЧИКОВ!

В связи с задержкой поступления из-за границы журнала "Космические полеты" № II высылаем Вам последующие номера.

CONTENTS

Editor:
G. V. Groves

Assistant Editor:
C. A. Simpson

Managing Editor:
L. J. Carter

Spaceflight Sales:
Shirley A. Jones

Advertising:
C. A. Simpson

***Spaceflight* Office:**
27/29 South Lambeth Road,
London, SW8 1SZ, England.
Tel: 01-735 3160.

DISTRIBUTION DETAILS

Spaceflight may be received world-wide by mail either through membership of the British Interplanetary Society or by non-member annual subscription. Details from the above address. Library subscription details available on request.

* * *

Spaceflight is distributed in the UK through newsagents by Profile Books Ltd., 1 Pontiac Works, Fernbank Road, Ascot, Berks SL5 8JH. Telephone 0344-884222. (If you have difficulty in obtaining ***Spaceflight*** please notify Profile Books in writing, stating the name and address of the newsagent).

* * *

Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society unless such is expressly stated to be the case.

* * *

Back issues of ***Spaceflight*** are supplied from available stocks at £2.00 (US$4.00) each, inclusive of surface mail delivery.

* * *

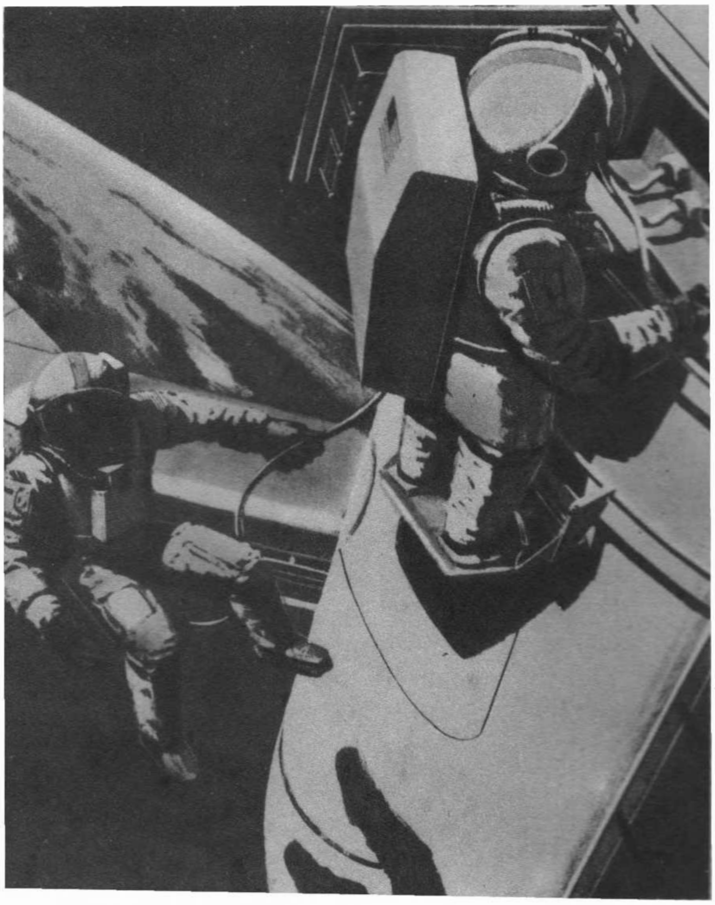
Published by the **British Interplanetary Society Ltd.**, (No. 402498). Registered office: 27/29 South Lambeth Road, London, SW8 1SZ, England.

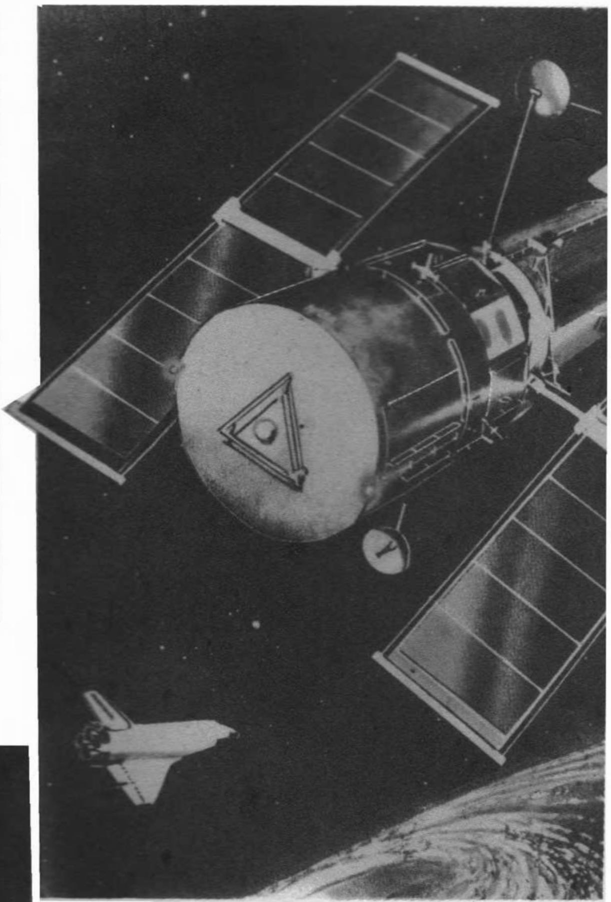
* * *

Vol. 28 No. 12 December 1986

CLARITY FROM

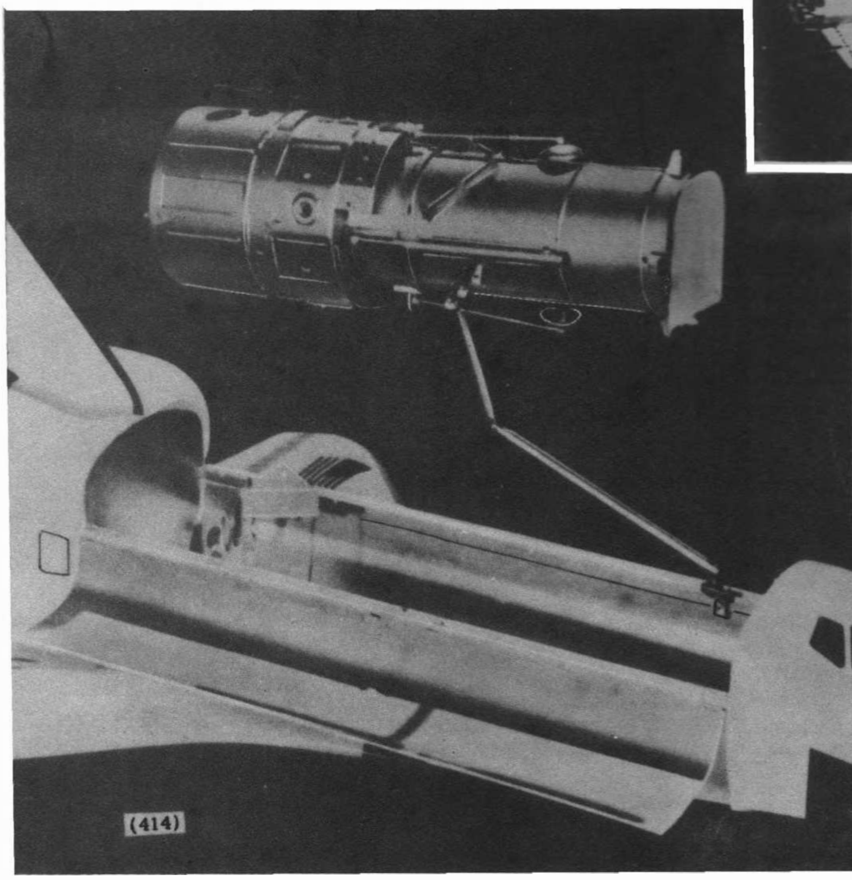
Our picture sequence highlights some of the main features of NASA's Hubble Space Telescope now scheduled to be one of the early Shuttle payloads when launchings resume in 1988.

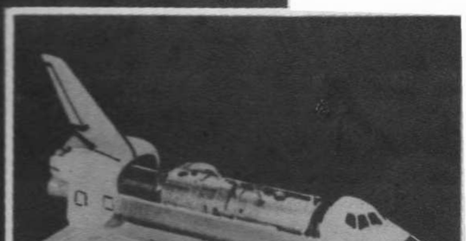




Captions (from lower right to lower left)

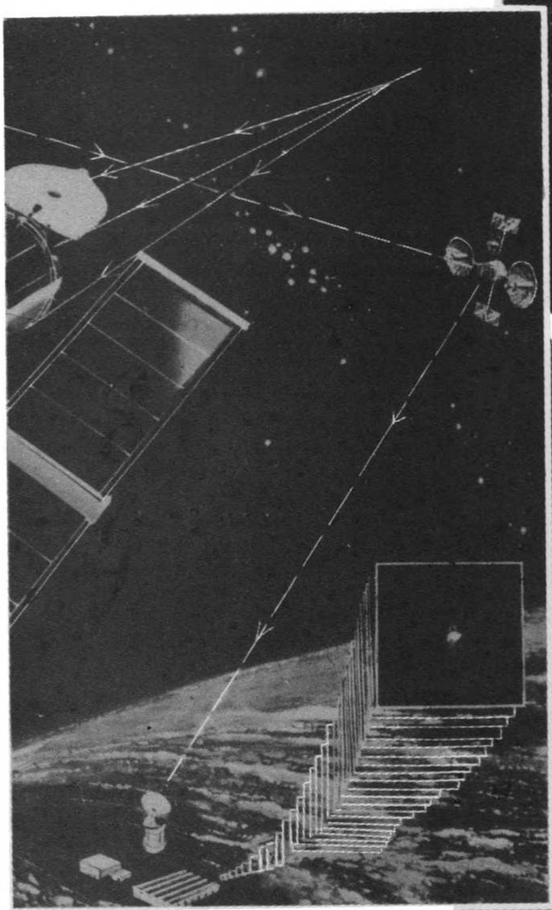
The Space Telescope is moved from the clean room at Lockheed's Sunnyvale Facility in May 1986. The Space Telescope is stowed in the cargo bay of the Space Shuttle Orbiter. On reaching orbit, the manipulator arm removes the Space Telescope from the cargo bay and then releases it.

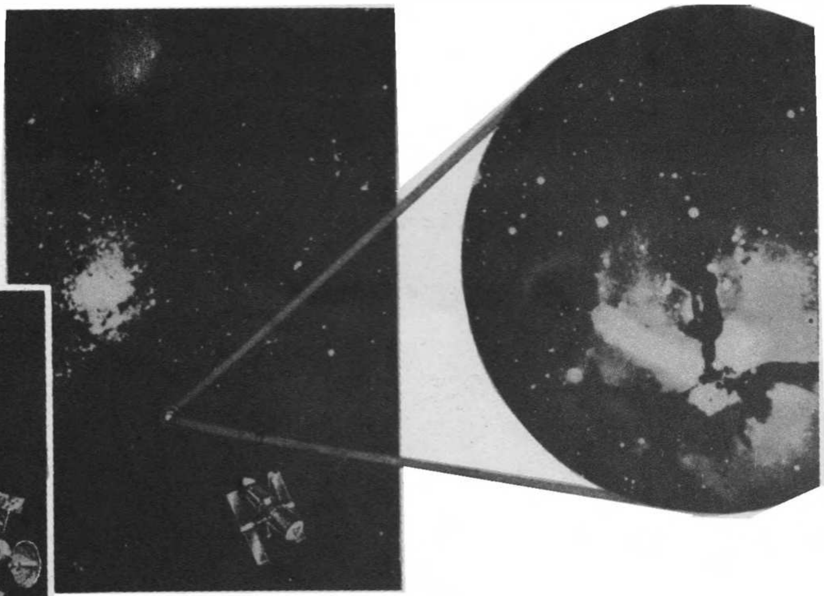


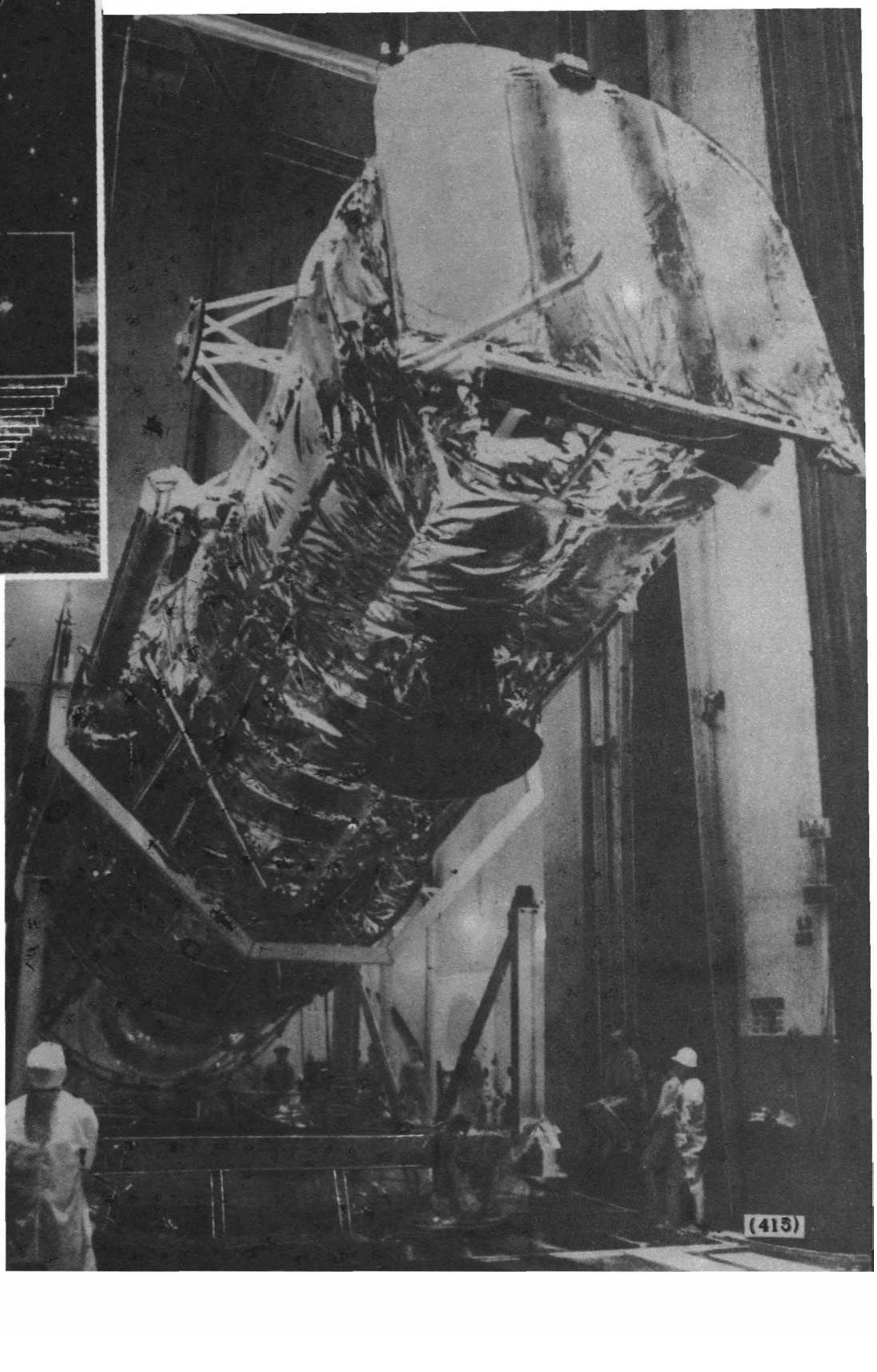


Pictures:
NASA and Lockheed.

ORBIT







The new telescope will be able to peer far out into space and back in time, producing images of unprecedented clarity of galaxies, star systems, and some of the Universe's more intriguing objects: quasars, pulsars and exploding galaxies. *Spaceflight* presents a special feature on the "Telescope in Space" beginning on page 440. A one-fifth scale model of the telescope is now on display in the newly-opened Space Gallery at the Science Museum, London (see page 436).

Captions (from top left to top right)
Astronauts arrive at the Space Telescope to carry out in-orbit maintenance or to replace instruments, batteries or other modules. On entering the telescope radiation strikes the primary mirror, is reflected back to the secondary mirror and reflected again to a focus. Instruments pick up the image which is transmitted via a Tracking and Data Relay Satellite to the ground station at White Sands, New Mexico, which in turn transmits it to the Goddard Space Flight Center. The circular picture shows how the Space Telescope will enlarge the very small circled area on a sector of the night-sky as it appears to an Earth-bound telescope.

Soviets Play It Safe

Sir, I have recently noticed a rapidly developing split among observers of the Soviet space programme. On the one hand are those who point to recently declassified United States Department of Defense (DoD) data suggesting that the Soviets are developing a range of new rockets and advanced spacecraft, including:

- A Saturn-V class launch vehicle.
- A Titan-class launch vehicle with cryogenic LOX/LH_2 propellants, which, we are told, may already have flown.
- A large Space Shuttle-type spacecraft, which may be launched on a modification of the Saturn-class launcher.
- A small Hermes-class spaceplane.
- A large, twelve-person space station, presumably to be launched on the Saturn-V class vehicle.

Other people have pointed to recent improvements in current Soviet vehicles, including:

- The development of a high energy upper stage for the Proton, using exotic high-energy propellants and possibly used to launch the Mir space station, as recently speculated in *Spaceflight*.
- The development of the Mir Station itself, which, while a vast improvement over the Salyut, is far from the super station expected by the DoD.
- Continuing improvement of the basic Soyuz human transport, beginning with the Soyuz-T and now culminating with the Soyuz-TM.
- Development and continuing use of the Progress automated transport.

This continued use and improvement of older equipment has caused some to argue that the Soviets are not likely to introduce the long-awaited Saturn- and Shuttle-class technologies in the near future. Why spend money on old rockets when new ones will soon be in service? While granting that few of us outside either nation's defence establishments (and possibly within) have any way to know the truth about the DoD claims, I would like to suggest that both positions may, at least in part, be correct.

It may be that the Soviets are unwilling to abandon tried and true spacecraft until new ones are fully developed. Thus, there could be a certain amount of overlap between the development of a new generation of Soviet spacecraft and the abandonment of the earlier generation. The Soviets have in fact shown a willingness to operate several complementary programmes at once, witness the multiple generations of military observation satellites currently in use. The presence of massive new launch pads and Shuttle-class runways, photographed for public consumption by the civilian Landsat and SPOT observation satellites, does indicate that at least some sort of new launch vehicle is being deployed.

The evidence suggests to me that the Soviets may have two entirely separate programmes for human space flight – possibly under completely separate managements. Since money is still being invested in them, the Proton, Salyut Mir, Soyuz, et al, may be expected to fly for the foreseeable future. They may continue to evolve into a complete, expendable space transportation system, similar to but more comprehensive than the one which the United States once considered developing with the Gemini/Manned Orbiting Laboratory.

Meanwhile, the revolutionary developments of high energy rocketry, reusable shuttle craft, and heavy space stations need not be rushed prematurely into service, since operational requirements are being met by the older systems. This approach is manifestly safer and of lower risk than the United States' exclusively revolutionary approach to the development of space technology, and in the light of the loss of Challenger may in the long run be less expensive.

DONALD F. ROBERTSON
California, USA

Intermediate Range

Sir, In Philip Chien's interesting piece on the Delta launch vehicle, (***Spaceflight*** Sept/Oct 1986 p.337), he mentions its outgrowth from the Douglas Thor ICBM. In fact, the Thor was an IRBM, an Intermediate Range Ballistic Missile, some of which were based in the UK in the early '60s.

MIKE KITCHENER
Hitchin, UK

Saving Precious Payloads

Sir, With the loss of the Challenger Space Shuttle many satellites will have to be launched by the Atlas, Delta or Titan rockets. Potential losses on these expendable vehicles (like those we have seen earlier this year) could be reduced by incorporating a salvage pod, giving the payload a chance of being recovered.

We read about the up-grading of the escape systems on manned spacecraft yet there appears to be serious losses on the unmanned space programme. By building into payloads an extra fuel supply, rocket and housing with parachutes and floatation, range safety officers could effect a separation of the main body in an abort situation. If, on the other hand, the launch goes well there is extra fuel to maintain satellite orbit or perform minor orbital manoeuvres.

MIKE BROWN
Birmingham

CORRESPONDENCE

Armstrong on the Moon

Sir, In ***Spaceflight*** (Sept/October 1986, p.327), I have just read "Who Needs Space Artists?", which is a rather good article, although the names of the Scottish artists Ed Buckley and Gavin Roberts are omitted.

David Hardy says "...there is no still photo of ... Neil Armstrong." In the booklet, *"The First Lunar Landing – As Told By the Astronauts"*, there are photos of Armstrong on the Moon (pp. 7, 8 and 10). The first photo (p.7) was taken by Eagle's automatic sequence camera and shows Armstrong immediately after the famous "one small step," and shows the surface camera being lowered by what Armstrong called the "Brooklyn clothes-line."

The second picture (actually two photos) are on the next page, and show Armstrong using the surface scoop to collect the contingency sample. The third photo is the only one in colour showing Armstrong on the Moon. This was taken during the flag-raising ceremony, showing Armstrong on the left. Although the positions of Armstrong and Aldrin are not identified in this booklet (nor in *"Man on the Moon"* 1969, Galina Inc., Houston, p.14, lower left), they are in the special *National Geographic* for December 1969 (p.735) with a caption identifying who is who.

Incidentially, Arthur C. Clarke was absolutely right when he referred to the impossibility of identifying a person wearing a space suit (in "Jupiter Five" among other places). On later space missions, beginning with Apollo 14, both on the Moon and in Earth orbit on Shuttle missions, the commander has worn a coloured band on his suit.

JOHN H. FADUM
Florida, USA

David Hardy has been invited to respond to John Fadum's letter and writes as follows:

Sir, I agree with John Fadum that Buckley and Roberts are excellent artists, though their work seems to be limited mainly to books by Duncan Lunan. Their omission – along with a dozen or so US space artists, many of whom I mentioned in my slide-talk on which the article was based – was due purely to space limitations.

As to photographs of the first man on the Moon, the key word is *still* photo. I was of course aware that movie frames and shots from the automatic sequence camera – and indeed TV images – have been used as illustrations, but I referred to the type of high-quality image taken of Aldrin and the lunar landscape by Armstrong's Hasselblad. Richard Underwood (of NASA) and Douglas Arnold have interesting stories about the reasons for this, but again there is not space here to detail these!

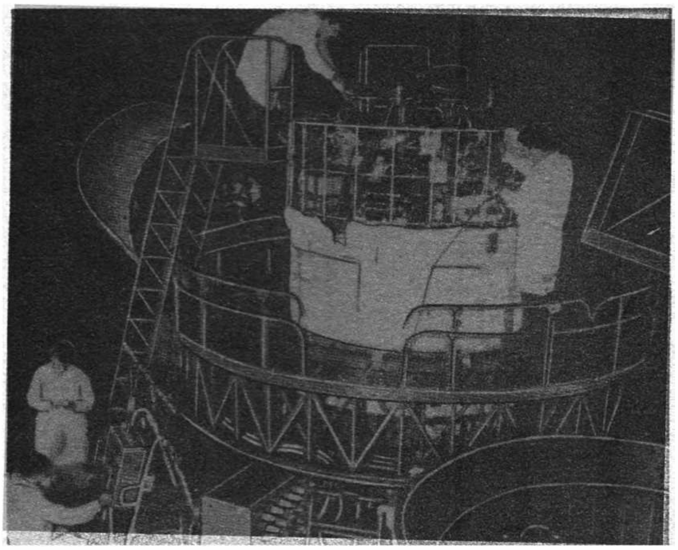
DAVID A. HARDY
Birmingham

Not Wanted Enough to Fund

Sir, There is one point in J.R. French's letter (***Spaceflight,*** November 1986, p.402) that I would like to contend, while accepting most of his comments.

I stated in my earlier letter that when Skylab was available a permanent space station was not wanted and I hold this to be true. The Shuttle and Space Station were indeed planned and proposed as a single package and in that sense NASA at least wanted them both. However, the Space Station was dropped and it is this fact which led to my statement that it was not wanted – at least not wanted by the US Government enough to fund it and, for better or worse, that is surely what is significant when deciding whether a project was wanted or not.

PETER R. HALL
Aylesbury, Bucks



Satellite Identification

Sir, Perhaps the readership of your magazine could identify the satellite and rocket stage in this recently published Soviet photograph (1). The caption identifies the scene as an oceanographic satellite in the Plesetsk Cosmodrome. It is likely that the rocket stage is the orbital stage of a variant of the F class booster. The satellite could be either Cosmos 1500 or 1602, both described by the Soviets as oceanographic satellites, but does not resemble the model of Cosmos 1500 exhibited at the 1985 Paris Air Show (2). In the background of the photo appears the nose of a C class booster, although the satellite is probably too large to have been launched by this booster.

DAVID ANDERMAN
California

References

1. "Cosmonautics – USSR", Mashinostroeniya Publishers, Moscow, 1986 page 254.
2. "The Soviet Year in Space 1985", Nicholas L. Johnson, Teledyne Brown Engineering, Colorado Springs, 1985, Page 34.

Shuttlecraft

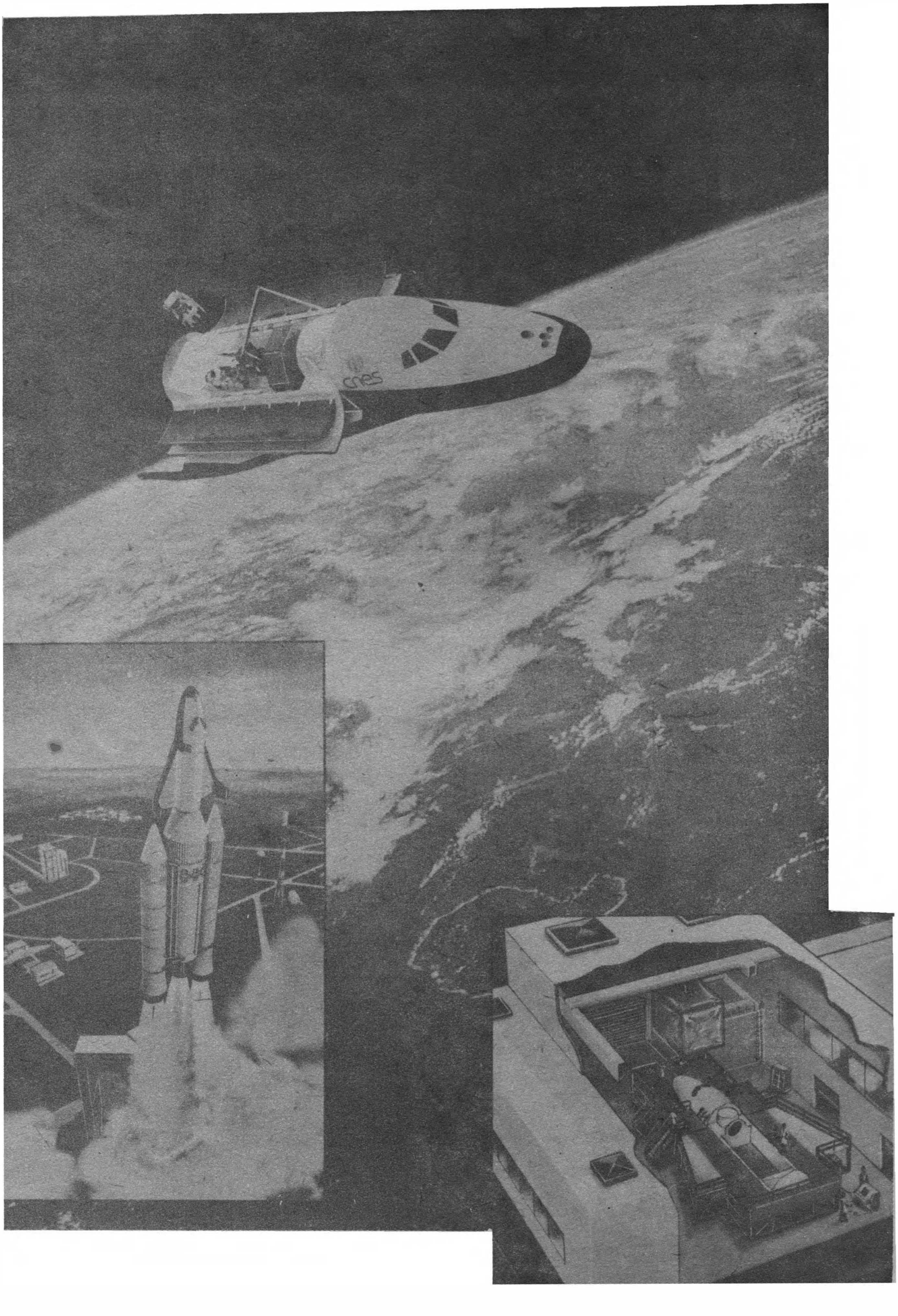
Sir, If Hermes ever becomes a reality it will no doubt represent the peak of European achievement and endeavour. Is it therefore appropriate that it should be described as a 'mini-shuttle' as though it were a diminutive copy of the US Shuttle? There may indeed be an official term to describe a relatively small spaceplane, if so no one seems to be using it and for this reason I humbly suggest that 'shuttlecraft' may suffice. Perhaps the Hermes Shuttlecraft is born?

PETER R. HALL
Aylesbury, Bucks

Lunar Landing

Sir, When the Eagle first landed on the Moon in July 1969, I was watching and listening to the television at the time. My pulse rate just prior to the Eagle landing was 60 beats per minute. When the Eagle landed on the Moon my pulse rate climbed to 80 beats per minute. I think this conveys the excitement I was experiencing, particularly since I had been waiting 20 years for that moment.

DAVID R. KEEDY
Tyne and Wear


cnes

EUROPEAN RENDEZVOUS

HERMES DECISION – STUDIES BEGIN

The Hermes mini-shuttle has been officially incorporated into the framework of the European Space Agency (ESA) with the start of studies this month (December) known as the Preparatory Programme.

A formal decision to begin the Preparatory Programme was taken by the ESA Council at its meeting on October 22-23.

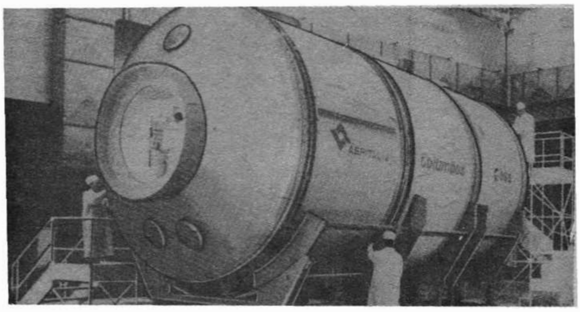
Cost of the studies is estimated at 48 MAU (Million Accounting Units, 1 AU = \$0.8 approximately) and a final decision on whether or not to proceed with the French-led project will be taken in the latter half of 1987.

This decision will be taken at Ministerial level and will combine with other elements of Europe's long term space programmes which include Ariane 5 and the Columbus Space Station module.

The industrial work included in the preparatory programme will aim on the one hand to arrive at a detailed definition of the shuttle and the associated ground segment requirements, together with the requisite basic technology studies, and sketch out a first definition of the technology for extra-vehicular activities (EVAs).

An ESA team to take charge of this programme is being set up. Part of the staff will work in Toulouse, in close collaboration with CNES (the French National Space Agency) to whom ESA will be delegating a number of tasks.

Hermes is a European cooperative venture to provide Europe with access to space for orbital servicing of space platforms, satellites and space stations. Total length: 15.5m; Width: 12.2m; Height: 5.1m; Payload: 4.5 metric tons; Crew: 2 to 6 astronauts. The System prime contractor is CNES; the Hermes prime contractor is Aerospatiale. *Lower right:* Hermes is refurbished and readied for launch at the Toulouse Space Centre. *Lower left:* Lift-off of Hermes on top of Ariane 5 from the Guiana Space Centre.



Columbus Space Station module.

ORBITAL REVOLUTION

Smith Associates, one of the UK's leading firms of system engineers, is carrying out a far-reaching study of the future uses of near-Earth space. The main purpose of the project is to identify new applications that would arise from revolutionary, rather than evolutionary, developments in space technology.

SA will be looking at a large number of possible uses of near-Earth space, extending well into the next century. A parallel study, covering the period up to the year 2000, will also be conducted by Logica, working as a subcontractor to SA. The two firms will work independently and then compare their conclusions.

Three important factors that will be taken into account are the future availability of a recoverable single stage to orbit (SSTO) vehicle, the potential reduction in the cost of achieving low Earth orbit and a large launch capacity.

However, according to Project Manager, Dr. D.R. Wilkinson, the scope of the study has been deliberately left open to allow hypothetical applications and technical advances to be considered. Drawing on the expertise accumulated in a variety of space and other projects, SA will examine the feasibility of many radical new ideas, some of which may depend on technology that is not even in development today.

Current space projects at SA include the development of special purpose electronic hardware in connection with the ground segment of Skynet 4 and research into paralled computing technology for on-board satellite signal processing. SA is also contributing to the definition of the UK data centre to handle the output from the European remote sensing satellite ERS-1.

★ ★ ★

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

United States/Soviet Cooperation

The United States and Soviet Union have been involved in detailed talks on future scientific exchanges, but have not discussed the possibility of a joint manned mission to the planet Mars, according to NASA administrator James C. Fletcher.

Dr. Fletcher, speaking at a Worldnet television news conference to scientists and journalists in Bonn, Bern, Brussels, London, Paris and Rome, said: "Right now most of the discussions with the Soviet Union do not involve manned missions of any kind, but primarily scientific exchanges.

"Having said that, though, most of us look forward to the day when we will be sending humans to Mars; establishing bases on the Moon; and ultimately, sometime in the next century probably, establishing a human base on Mars."

US space experts met with Soviet counterparts in September to discuss potential cooperation in Mars exploration and the medical aspects of manned space flight. Frederic D'Allest, head of Arianespace, which represents Europe's Ariane rocket, told reporters at about the same time that space scientists are beginning to consider seriously the possibility that the United States, the Soviet Union and Western European nations could mount a joint mission to Mars.

The United States and the Soviet Union have not been involved in a major cooperative space effort since manned spaceships linked up in orbit during the Apollo-Soyuz flight in 1975.

SOVIET-FRENCH MEETING

The annual Soviet-French meeting on co-operation in space research took place in Yereven, the capital of Soviet Armenia, on October 21.

Vladimir Kotelnikov, Chairman of the Intercosmos Council, stated that co-operation between the two countries now extends from the production of scientific instrumentation to the creation of spacecraft service systems and joint ground facilities.

In the last 20 years about 50 joint experiments and projects have been implemented. Communications engineers are currently working on plans for a satellite TV link.

WEATHER SATELLITE DELAYED

Launch of the GOES-H weather satellite by the United States has been delayed to February 19, 1987 at the earliest because of technical problems with the spacecraft's imaging system. Lift-off using a Delta rocket had been scheduled for December 4.

TITAN PADS REPAIRED

Repair work has been completed at Space Launch Complex 4 at Vandenberg AFB following the April 18 1986 explosion of a Titan 34D rocket that caused extensive damage to the two pads, ***writes Joel Powell.***

Wiring and plumbing on the gantry tower of the adjacent SLC-4W pad used by Titan 3B was repaired first, but the damage to the out-buildings and concrete surfaces of the SLC-4E pad from which the ill-fated Titan ascended required additional time. The USAF expects the Titan 34D to be ready for launches beginning in February 1987.

Meanwhile at Cape Canaveral, Martin Marietta is modifying the mobile launch tower and gantry of Complex 41 for use by the new Titan IV launch vehicle, formerly known as Titan 34D-7 Centaur. The work involves extensions to access work platforms and new cryogenic propellent feed lines. Martin Marietta will produce 23 Titan IV's for the Air Force, which will be launched at a rate of four per year from the Cape beginning in 1989. A higher launch rate is possible should the Air Force abandon plans to utilise the Space Shuttle from Vandenberg AFB. ***Spaceflight,*** Sept/Oct '86.

NEW ROCKET PLANT FOR DELTAS

McDonnell Douglas is to open a rocket manufacturing plant in Pueblo, Colorado next spring in support of the revived Delta Launch Vehicle programme.

The $1.7 million facility will be used initially for final assembly of the unmanned Delta rocket. The company is considering adding other work and another building in Pueblo later. Some 200 people will be employed by 1988.

The 5,760 sq m plant will be in the Pueblo Memorial Airport industrial complex. By March, about a third of the building will be available for occupancy, with the remainder ready by May.

McDonnell Douglas has built and launched Delta rockets since 1960. NASA interrupted production of the Delta in 1984 at the McDonnell Douglas Astronautics Company plant in Huntington Beach, California. However, the recent NASA order for three new rockets and other potential orders caused the Company to revive the programme and re-evaluate the location of future assembly operations.

All future Deltas will be assembled in Pueblo, although Delta programme management, engineering and all fabrication work will remain in Huntington Beach.

The McDonnell Douglas Delta programme has a success record of 98 per cent over the past 45 launches.

SATELLITE DIGEST – 197

Robert D. Christy

Continued from the November 1986 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1766, 1986-55A, 16881
Launched: 2109, 28 July 1986 from Plesetsk, by A-2 or F-2.
Spacecraft data: Possibly a truncated cone with a pair of sun seeking solar panbels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 635 x 666 km, 97.80 min, 82.53 deg.

COSMOS 1767, 1986-56A, 16883
Launched: 0830, 30 July 1986 from Tyuratam by A-2.
Spacecraft data: Not available.
Mission: Not know, decayed from orbit 16 August 1986 over the Indian Ocean.
Orbit: 197 x 206 km, 88.54 min, 64.89 deg.

MOLNIYA-1 (67), 1986-57A, 16885.
Launched: 1506, 30 July 1986 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both with in the USSR and abroad.
Orbit: Initially 617 x 40627 km, 735.87 min, 62.68 deg, then lowered to 622 x 39873 km, 718.79 min to ensure daily repeats of the ground track.

COSMOS 1768, 1986-58A, 16890.
Launched: 0920, 2 August 1986 from Plesetsk by A-2
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Photo-reconnaissance, all or part of the payload was an Earth resources package. Recovered after 14 days.
Orbit: 259 x 273 km, 89.89 min, 82.58 deg.

COSMOS 1769, 1986-59A, 16895.
Launched: 0507, 4 August 1986 from Tyuratam by F-1
Spacecraft data: Cylindrical, probably about 7 m long and 2 m diameter, equipped with solar cell panels and with a mass around 5000 kg.
Mission: Electronic intelligence gathering over ocean areas.
Orbit: 429 x 443 km, 93.31 min, 65.03 deg, maintained by a low thrust motor during the operational lifetime.

COSMOS 1770, 1986-60A, 16897
Launched: 1330, 6 August 1986 from Tyratam by A-2
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 238 x 281 km, 89.71, 64.85 deg, manoeuvrable.

AJISAI (EGS), 1986-61A, 16908
Launched: 0845*, 12 August 1986 from Tanegashima by H-1
Spacecraft data: 2.15 m diameter ball, covered in mirrors and laser retro-reflectors. The mass is 685 kg.
Mission: Experimental Geophysical Satellite, a passive geodetic target carried as a payload on the test launch of the new H-1 launch vehicle. The launch vehicle upper stage (1986-61C) carried MABES – Magnetic Bearing Experiment System, testing the operation in orbit of a flywheel in a magnetic bearing.
Orbit: 1479 x 1497 km, 115.66 min, 50.01 deg.

FUJI (JAS-1), 1986-61B 16909.
Launched: 0845*, 12 August 1986 from Tanegashima by H-1.
Spacecraft data: 26-faced, solar cell covered polyhedron, 0.5 m across and weighing 50 kg.
Mission: Amateur radio relay satellite, carried as a secondary payload on the H-1 launch vehicle test. JAS stands for Japanese Amateur Satellite.
Orbit: 1479 x 1497 km, 115.66 min, 50.02 deg.

COSMOS 1771, 1986-62A, 16917
Launched: 1257, 20 August 1986 from Tyuratam by F-1.
Spacecraft data: Combined satellite and final rocket stage, around 7 m long and 2 m diameter with a mass around 5000 kg. A slot-type radar aerial is fixed to one side of the body. Power is provided by a nuclear reactor.
Mission: Radar reconnaissance over ocean areas.
Orbit: 251 x 265 km, 89.67 min, 65.01 deg, maintained by a low thrust motor during the operational lifetime. Later, the nuclear power source is expected to be boosted to a 900-950 kilometre high, circular orbit to delay re-entry into the Earth's atmosphere.

COSMOS 1772, 1986-63A, 16918
Launched: 1105, 21 August 1986 from Plesetsk by A-2.

Chinese Launch Monitored from UK

China launched an Earth resources satellite using its Long March 2 rocket on October 6. Lift-off occurred at 0540 GMT and the payload was recovered five days later on October 11 at 0420 GMT.

The launch, from China's Jiuquan launch centre in the Gobi desert, was not announced officially until after completion of the mission. However, details were revealed in the West within several hours of lift-off by Geoffrey Perry of the UK's Kettering Group.

He told *Spaceflight* that his monitoring equipment had picked up telemetry signals at 0832 GMT on the day of launch and had continued to receive information for the entire mission.

The satellite was the 19th launched by China since 1970.

INTERNATIONAL SPACE REPORT

UK Collaborates in Space Astronomy

UK-Soviet Research

X-ray astronomy is expected to provide a basis for long-term UK/Soviet collaboration following a visit by a BNSC delegation to Moscow at the end of September 1986 (*Spaceflight*, November 1986 p.372).

The first major joint effort to be undertaken by the Soviet Institute of Space Science, Moscow and the British National Space Centre (BNSC) is the X-ray project, named 'Roentgen', in which the Federal Republic of Germany and the Netherlands are also involved. An X-ray telescope designed with the participation of Birmingham University is scheduled for a Soviet launch in 1987.

Possibilities for future collaborative space research, identified during the Moscow discussions, include measurements in both the extreme ultraviolet (XUV) and X-ray regions of the spectrum. The development of UK instruments has been proposed for mounting on a Soviet XUV and X-ray astronomy satellite in the early 1990's. The UK and USSR organisations concerned are now to examine collaborative arrangements in more detail.

UK-FRG-US Joint Project

Another international astronomical project, formally agreed in 1983 after several years of preparation, also spans both the XUV (60-300A) and X-ray (6-80A) wavelength bands. This is the 'Roentgensatellit' or ROSAT project in which the X-ray band is covered by a large Wolter-1 X-ray telescope, developed in Germany, with one of the focal plane detectors provided by the US participants. The XUV band is covered by the UK's Wide Field Camera.

The instruments will conduct two simultaneous imaging surveys of the whole sky for a six-month period after which ROSAT will be used as a conventional pointing observatory to carry out a succession of long observations on cosmic sources in both wavebands, often studying new souces that the surveys are expected to cover.

The spacecraft to carry these instruments is being developed in Germany and was scheduled for a 1988 Shuttle launch before the Challenger accident. Present indications are that, if ROSAT remains in the Shuttle programme, long delays are to be expected. Faced with the possibility of such delays, the international project team, including the UK members, are actively investigating earlier launch options with the Atlas-Centaur as the prime candidate.

Alan Wells, Project Scientist, informs ***Spaceflight*** that ROSAT is not one of the projects under consideration for launch on a Soviet launch vehicle (**Spaceflight,** November 1986) and none of the principal participants in the Wide Field Camera programme has taken part in discussions about operational requirements for data collection from a Soviet-launched Wide Field Camera.

X-Ray Telescope To Fly On Japanese Spacecraft

A team from the University of Leicester and from the Science and Engineering Research Council's (SERC) Rutherford Appleton Laboratory (RAL) has recently delivered to Japan the largest X-ray detector ever built.

This was for the Astro-C satellite now being tested at the Japanese Institute of Space and Astronautical Science (ISAS) in Tokyo. The launch is scheduled for February 1987 on the new Japanese Mu 352 rocket. Astro-C will be of crucial importance to astronomers over the next few years because of its intrinsic power and the likelihood that no other non-Soviet X-ray missions will fly before 1990.

Astro-C carries three experiments. The University of Leicester, RAL and ISAS are providing the Large Area Counter, consisting of eight detectors with an area of some 5000 cm^2. This will study the variability in cosmic X-ray sources over time periods ranging from a fraction of a second to a number of months.

An All-Sky Monitor built by the University of Osaka will search for short bursts of X-rays from weak sources as well as dramatic changes in more powerful sources, and a Gamma Ray Burst detector from Los Alamos in the United States will monitor the sky for isolated flashes of gamma rays.

Astro-C will concentrate on observing the variation of X- and gamma-ray sources such as neutron stars or 'black holes', in order to understand the physical processes involved in high-energy emission.

An object cannot vary its luminosity faster than the time light takes to travel across it. So, measuring the fastest significant variation in output is a means of placing limits on the size of the emitting region. Converting this size limit to a limit on the mass of the object may be rather straightforward because, in a neutron star or 'black hole', mass and radius are directly related to one another.

This project was supported initially by SERC but now comes under the aegis of the British National Space Centre (BNSC).

Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 13 days.
Orbit: 354 x 414 km, 92.28 min, 72.87 deg.

COSMOS 1773, 1986-64A, 16920
Launched: 1140, 27 August 1936 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 173 x 345 km, 89.70 min, 64.87 deg, manoeuvrable.

COSMOS 1774, 1986-65A, 16922.
Launched: 0804, 28 August 1986 from Plesetsk by A-2-e
Spacecraft data: Probably similar to the Molniya satellites, in which case it has a cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries sensors and a solar panel array set in a plane at right angles to the main axis of the body. Stabilisation is probably by the use of momentum wheels. The length is about 4 m, the maximum diameter is about 1.6 m, and the mass around 1800 kg.
Mission: Part of the USSR's ballistic missile early warning system.
Orbit: Initially 599 x 39236 km, 707.26 min, 62.93 deg then raised to 601 x 39799 km, 718.31 min, 62.95 deg to ensure daily repeats of the ground track.

Soviets Push Launch Offer

Early Flights at Low Price

The Soviet Union has reaffirmed its offer to fly commercial payloads into Earth orbit for other countries and international organisations.

A new organisation, Glavkosmos, set up last year, has been charged with the responsibility of handling the commercial side of Soviet space operations.

The first commercial launch will take place in 1987 when the Indian Remote Sensing (IRS) satellite will be put into orbit by the Proton booster.

Possibilities of similar cooperation are currently being discussed with Finland, Iran and some Latin American countries.

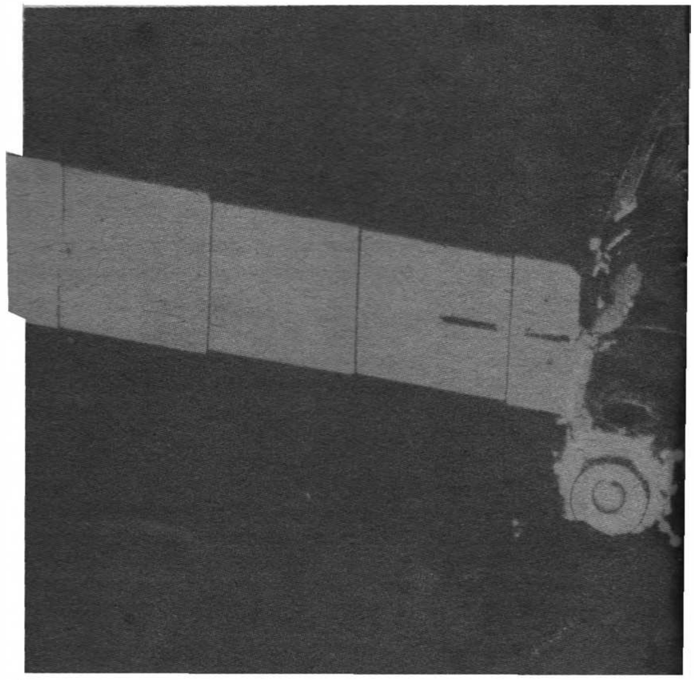
Among the incentives on offer to potential customers are cheaper prices – Inmarsat (of which the Soviet Union is a member) has been offered a launch at 20 per cent less than the cost of using the US Space Shuttle or Europe's Ariane – and quicker launch opportunities, particularly following the problems faced by the West in 1986.

Proton, the rocket used for all Salyut and Mir space stations, can be used in three stage versions (for payloads of up to 20 tons into low-Earth orbits) or with four stages (two tons into geostationary orbit).

Dmitry Poletayev, department chief of Glavkosmos, has also stressed that representatives of firms involved in the manufacture of any satellites launched by Proton will be able to accompany the payload at all stages of integration.

Inmarsat's list of internationally available launchers is understood to have included Proton as suitable for its requirements. But a year ago the US, who is also a member of Inmarsat, opposed the use of Proton on the grounds that US satellite equipment would be subject to Soviet examination during delivery of the payload to the launch site. In spite of assurances from the Soviet side, Inmarsat has yet to take up the Soviet offer and by not doing so is open to the criticism of incurring unnecessary expense amounting to several million US dollars.

* * *



The Mir Space Station.

LONG DURATION

The next stage of the Mir programme is due to start in early 1987 and one of the initial aims is to keep a crew in space for 10 months, *writes Neville Kidger*.

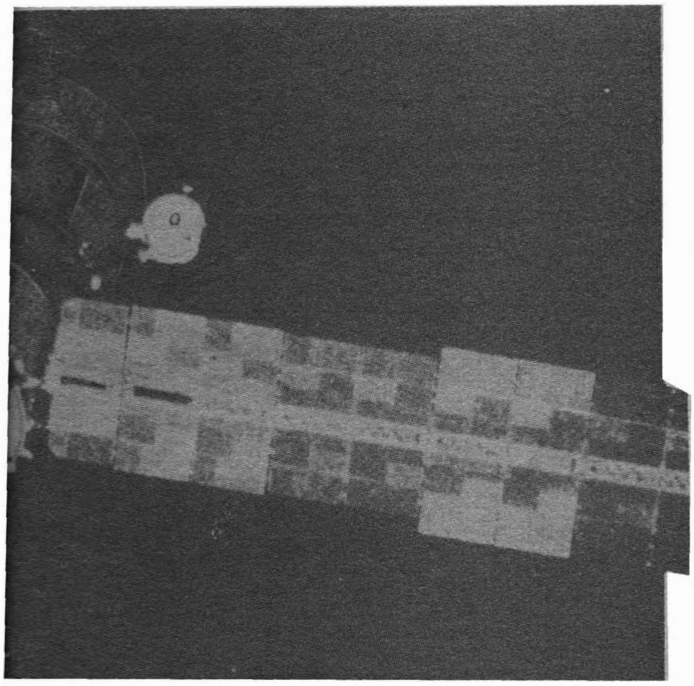
Early next year a large Cosmos Module is expected to dock with Mir. It will be dedicated to astrophysics research and house a large X-ray facility – the Complex X-Ray Observatory – which includes equipment supplied by the Soviets, the Netherlands, the UK, ESA and West Germany.

The X-ray observatory will view some 20 targets in its initial phase of operations. Other science modules over the next years will also contain a degree of international participation with several countries being invited to send cosmonauts to Mir to conduct research there.

Currently, there are definite plans for three international missions:

- In the second half of 1987 a Syrian, either Munir Habib or Muhamid Faris, will make a flight to Mir. The men have conducted basic training for the flight and are waiting to be assigned to prime and reserve crews. The flight, details of which are still being officially discussed, may include an EVA by the Syrian cosmonaut.

- In 1988 French cosmonaut Jean-Loup Cretien will make his second flight on a Soviet mission when he flies to Mir. The current plan calls for a month-long stay on the station and an EVA. Technical and biological experiments will form a large part of the programme and will include an improved version of the ecograph flown with Cretien to Salyut 7 in 1982. The EVA will see the erection of a four metre diameter deployable antenna for satellite-to-satellite communications. Michel Tognini, one of CNES's seven



MISSION FOR MIR

new astronauts, is back-up to Cretien. The men began training in the USSR in September.

- An unnamed Bulgarian will fly to Mir, also in 1988, to conduct a variety of weightless experiments. The first Bulgarian in space, George Ivanov, was unable to perform experiments in Salyut 6 in 1979 when a problem with the engine of the Soyuz 33 ferry spacecraft forced cancellation of the docking and also almost stranded him and his Soviet commander, Nikolai Rukavishnikov, in orbit. The new flight will include smelting of an aluminium alloy that could be used in the construction of space vehicles.

Spaceflight's series of reports by ***Neville Kidger*** on Soviet manned space activities for 1986 are concluded below.

On July 1 it was announced that the orbit of the station was at 372 x 343 km; period 91.41 minutes; inclination 51.6 degrees. Following their transfer back to the Mir core space station, cosmonauts Leonid Kizim and Vladimir Solovyov gave a TV report in which they described installing a new information system, called Strela (Arrow). They said that the system was an experimental one and featured data on a display screen that would normally be contained in Mir's on-board documentation. In addition, it monitored many of the station's systems, monitored their status and received information uplinked from the Flight Control Centre (FCC).

On July 3 Kizim passed the accumulated stay time in space of Valeri Ryumin who has spent 361 days 21 hours 31 minutes and 57 seconds in flight during his three space missions. (Solovyov was 12 d 19 h 42 s behind his commander in total time in space).

The two cosmonauts were involved with photography of Earth and medical experiments. It was also reported that they had installed unspecified "equipment" onto the station.

Earth observations continued until July 14 when the Soviets revealed that the cosmonauts were "completing [their] research and experiments on Mir". Western reports had earlier indicated that the two would stay in space until September.

Before the return, however, they participated in a remote sensing experiment which was taking place in the GDR. The "Geoex-86" experiment, directed by the Interkosmos organisation, involved land, air and space facilities including Mir and the Cosmos 1602 satellite.

On July 15 it was revealed that the men were to land the next day. They had spent the day organising the station for a period of autonomous flight and packing away the results of their work.

Returning to Earth

At 0907 (all times GMT) on July 16, Soyuz T-15 conducted a "slow and smooth" undocking from Mir. A small separation manoeuvre was later performed and at 1023 the Soyuz Orbital Module was cast off. At 1205 the command was given for retrofire which lasted for 3.5 minutes. At 1211 the descent cabin, with the cosmonauts aboard, entered the upper layers of the atmosphere. Touchdown was at 1234.

At the landing site the cosmonauts were seated in special chairs and interviewed. They reported that the station was in good working order and ready to be used again. Kizim and Solovyov were then helicoptered to the town of Arkalykh and then flown by plane to Baikonur. The next day the men were seen walking by journalists but they did not give any interviews – unusual for a Soviet crew just back from space. Kizim had reportedly lost 0.5 kg in weight and Solovyov 5 kg.

There was speculation as to why the cosmonauts had returned "early" from space. The most commonly held theory among western analysts was that the men had accomplished all their tasks and that they had been "bored" on Mir for a second time because the original flight plan probably included docking of the first of Mir's heavy Cosmos Modules. However, it was known from an interview given by Dzhanibekov in Australia, that the modules were running late and that none were due for launch before early 1987. There was also a rumour that a small air leak had developed in the Mir multiple docking unit but that could not be confirmed.

Orbital Manoeuvres

At a press conference in Moscow on August 1 Kizim and Solovyov, together with specialists, described the flight. It was said that the men had conducted some 150 sessions of work including investigations into the disciplines of geophysics, biology, astrophysics and technology. They had brought somed 400 kg of materials from Salyut 7 to Mir, including their EVA suits.

In space, the Salyut 7/Cosmos 1686 complex which had been left in autonomous flight by Kizim and Solovyov, was the next focus of attention. Between August 19 and 22 the orbit of the complex was raised and although the Soviets said that the work of the station in the manned mode had been accomplished, it was stated that the complex would be revisited at some future date with a view to seeing how its systems had coped with extended exposure to space conditions.

On August 23 the Soviets announced completion of the manoeuvres and gave details of the new orbit – 492 x 474 km; period 94 minutes; inclination 51.6 degrees. Both Salyut and Cosmos module's propulsion system had been used in the manoeuvres. The orbital height gives the complex an estimated lifetime of "at least eight years".

Provision has been made to exercise telemetry control of the complex in its higher orbit. The condition of the airtightness of the habitable section, the tanks, hydraulics and pneumatic mains will all be monitored until the service life of the systems ends and radio contact is lost. A further crew could be sent to the station to bring back samples of various components before the complex makes a controlled destructive re-entry.

Maintaining a Space Station

by Dietrich Haeseler

Since 1971 a Soviet space station programme, called Salyut, has been conducted in near Earth orbit. A clear result that emerges from the Salyut programme is that maintenance of the crew sets the main demand for space station supplies (at 13.4 kg per day) compared with only 2.4 kg per day for experimental work in the station. A need can therefore be identified to make the role of man-in-space more cost effective by the introduction of increased automation and robotics. Even so, the present Soviet launch capability is seen to be adequate to maintain a permanently manned space station.

Salyut Mass Breakdown

Masses of individual spacecraft [1-6] are shown in Table 1. The total payload mass of a Salyut station at launch is unknown, but the mass of the scientific equipment has been said to be around 1500 kg and over 2000 kg for Salyut 6 and 7 respectively [7]. Payload mass includes the crew for Soyuz and Soyuz-T, and cargo is assumed to replace the third seat in a two-seater Soyuz-T.

For the module Cosmos 1669 masses were taken to be the same as for Progress, which was probably a prototype for a small scientific module to be used either docked to the space station or as a free-flyer. For Cosmos 1686 the payload mass has been published in Reference 8. No estimates of the mass and payloads of the return capsules of Salyut 3 and 5 are available.

Transport To Salyut And Back To Earth

Table 2 and Figure 1 give the annual mass totals launched into orbit and recovered on Earth. Only flights directly related to the Salyut programme are considered, including the failures of Soyuz 15, 23, 25, 33 and Soyuz-T 8, but not the launch failures of Soyuz 18A and Soyuz-T 10A.

Up to 70 t (one t equals 1000 kg) per year have been launched of which up to 12 t were payloads including crews. Of this, up to 17 t were returned to Earth, the payload being about 1.3 t with crew. This maximum return occurred during the busy years of the Intercosmos programme, when flights with international crews were for the most part not necessary to maintain Salyut operation. In typical years like 1982/5 about 9 t were returned, 0.7 t being payload including the crew.

The largest payloads delivered to Salyut are for maintaining life onboard and consist of consumables,

An interior view of a Salyut space station. Cosmonauts consider the inclusion of port-holes an essential feature of space station design, particularly on long-duration missions. The frequent opportunities for spectacular viewing of the Earth beneath have proved to be psychologically beneficial – and taking a photograph for the record irresistible!

Table 1: Mass Breakdown (kg) for Spacecraft in the Soviet Salyut Space Station Programme.

Spacecraft	Launched Mass	Launched Payload	Mass at Dedock	Recovered Mass	Recovered Payload	Mass at Deorbit	Crew Size
Salyut 1–5	18900	–	–	–	–	18900	(2)
Salyut 6, 7	19824	–	–	–	–	19824	(2–6)
Soyuz	6800	190	6350	2850	190	3500	2–3
Soyuz–T	6850	270	6200	3000	270	3200	2–3
Progress	7020	1920	4900	–	–	4900	–
Cosmos-Module	18000	4000	14000	5000	350	9000	(2)
Cosmos 1686	18000	8000	9500	–	–	9500	(2)

Table 2: Annual Transportation Performance in the Soviet Salyut Space Station Programme. All masses in metric tons (1t = 1000 kg).

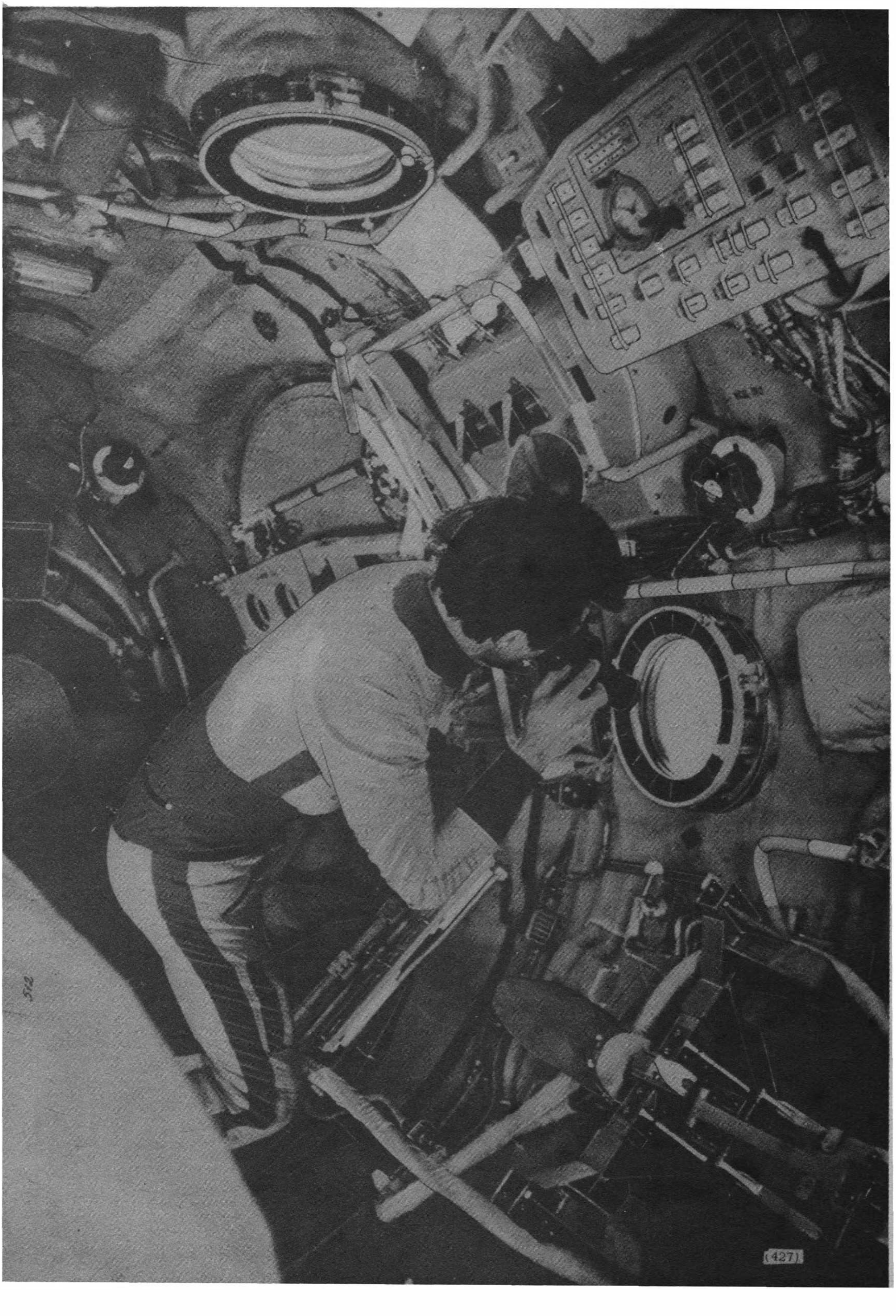
Year	Launched Mass	Launched Payload	Recovered Mass	Recovered Payload	Deorbited Mass	Crew-days	Cosmonauts	Salyut	Soyuz/ Soyuz-T	Progress	Cosmos Module
1971	32.5	0.54	5.70	0.54	25.9	77.3	6	1	10, 11	–	–
1972	–	–	–	–	–	–	–	–	–	–	–
1973	18.9	–	–	–	18.9	–	–	2	–	–	–
1974	51.4	0.38	5.70	0.38	7.0	35.5	4	3, 4	14, 15	–	–
1975	20.4	0.57	5.70	0.38	25.9	185.1	4	–	17, 18, 20	–	–
1976	32.5	0.38	8.55	0.57	7.0	102.5	4	5	21, 23	–	–
1977	40.2	0.57	5.70	0.38	25.9	83.5	6	6	24–26	–	–
1978	62.1	7.96	17.10	1.14	37.1	487.3	10	–	27–31	1–4	–
1979	48.3	6.60	11.55	0.84	28.4	350.0	4	–	32-34, T 1	5–7	–
1980	69.0	8.98	17 40	1.30	40.0	463.1	13	–	35–38, T 2, 3	8–11	–
1981	45.5	3.57	13.70	0.65	15.1	181.0	6	–	39, 40, T4	12	1267
1982	68.4	8.49	9.00	0.81	61.0	470.2	8	7	T 5–7	13–16	–
1983	45.7	8.38	11.00	0.89	25.2	304.9	5	–	T 8, T 9	17, 18	1443
1984	55.7	10.41	9.00	0.81	34.1	770.0	9	–	T 10–12	19–13	–
1985	45.7	12.38	6.00	0.54	16.2	419.0	5	–	T 13, 14	24	1669, 1686

Notes to Table 2:

Year–	1 January to 31 December.
Launched Mass–	Mass of all launched Salyut, Soyuz, Soyuz-T Progress and Cosmos-Modules including payloads; but omitting Soyuz soloflights and launch failures.
Launched Payload–	Total payload mass of Soyuz, Soyuz-T, Progress, Cosmos-Module including cosmonauts (80 kg each); but omitting that of Salyut as it is not known.
Recovered Mass–	Mass of all cabins landed on Earth including payload.
Recovered Payload–	Payload mass landed on Earth including cosmonauts (80 kg each).
Deorbited Mass–	Mass of all dedocked and deorbited vehicles burned up at re-entry in the atmosphere
Crew-days–	= Number of cosmonauts x flight time in days.
Cosmonauts–	Number of launched cosmonauts.
Salyut–	Numbers of launched Salyut stations.
Soyuz/Soyuz-T–	Numbers of launched Soyuz and Soyuz-T.
Progress–	Numbers of launched Progress.
Cosmos-Module–	Numbers of launched Cosmos-Modules.

All vehicles were recovered or deorbited in the same year that they were launched with the following exceptions:

Salyut 3	launched 1974, deorbited 1975
Salyut 4	launched 1975, deorbited 1977
Soyuz 20	launched 1975, landed 1976
Salyut 5	launched 1976, deorbited 1977
Salyut 6	launched 1977, deorbited 1982
Soyuz 26	launched 1977, landed 1978
Cosmos 1267	launched 1981, deorbited 1982, DM landed 1981
Still in Orbit:	Salyut 7 and Cosmos 1686



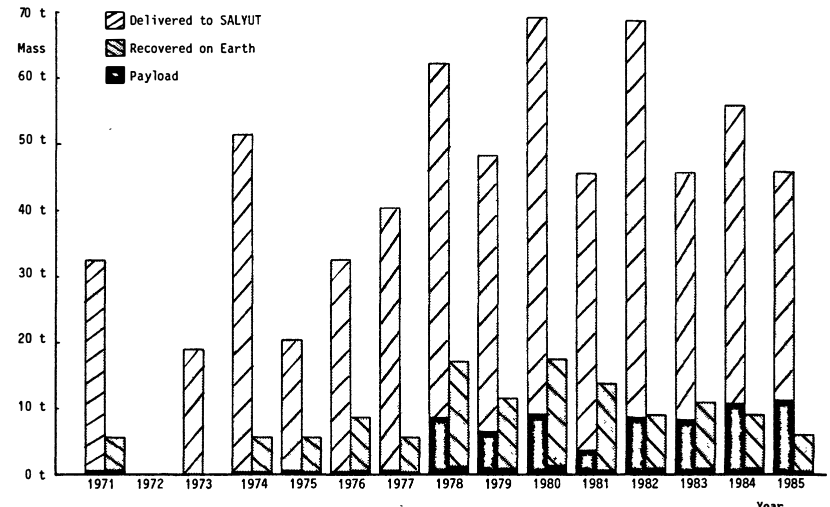
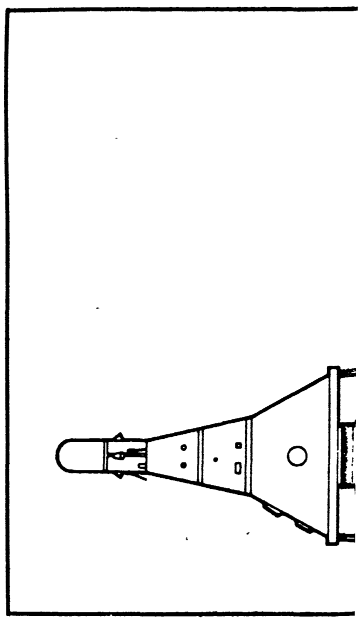


Fig.1: Annual mass totals launched into orbit and recovered on Earth.



spares and propellant to keep the station in orbit, (see Table 3 [9]). Used equipment and waste is thrown overboard and burned up in the atmosphere at re-entry some days later, either in small bags or in used Progress transporters. Thus, only the results of experiments like film, tapes, samples, as well as souvenirs are returned to Earth. The cargo capacity of the descent module (DM) of Cosmos 1443 was announced to be 500 kg, but it returned partially filled with only 350 kg of cargo, including not only experimental results but failed equipment as well [6]. Obviously there was not enough material to use the full capacity of the DM.

For the period 1978 to October 1984, which covers 3065 crew-days aboard a station, it is possible to assign the mass which each crewmember used per day. Of the total 15.8 kg per day, only 2.4 kg were for experimental work in the station, the remaining 13.4 kg being for consumables to keep the crew alive and the functioning of the station's systems.

Outlook for the Future

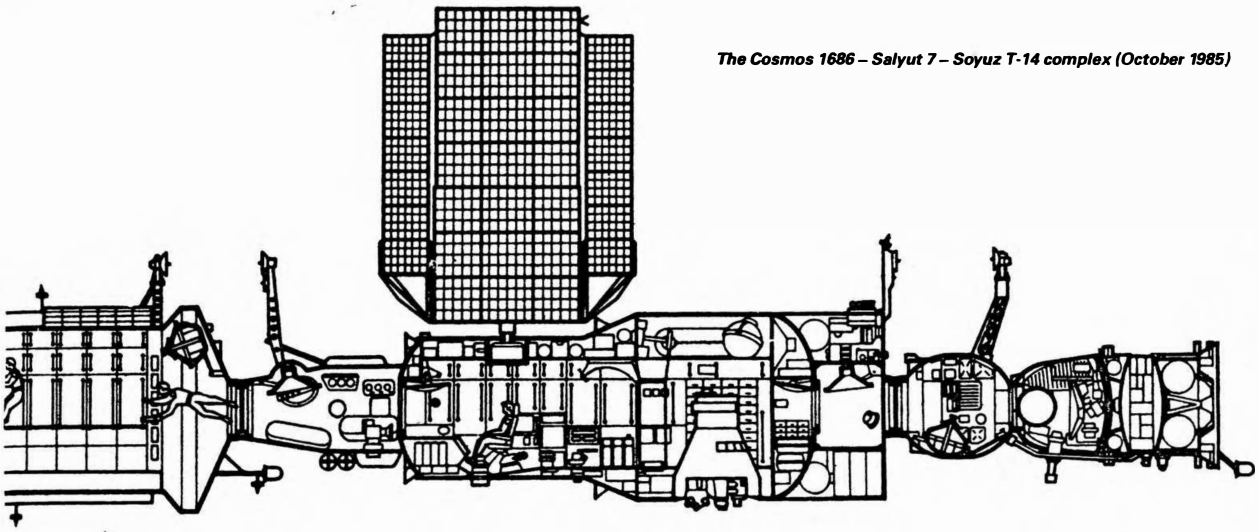
With the introduction of the Progress cargo transporter and the Cosmos space station modules, the Soviets have shown a capability for lifting large masses into near Earth orbit and for performing a space station programme on an even greater scale. In February 1986 they launched Mir, the centerpiece for a modular station, which, on completion, will consist of the basic Mir (20 t), two large modules (20 t each), two small modules (7 t each), a Soyuz-TM crew transporter (7 t), and either a second Soyuz-TM or a Progress (7 t). This configuration has been presented by an eastern source [10], and would represent a complex with a mass of about 90 t in orbit. Another source cites a configuration resulting in a 140 t mass [11].

Assuming that a four person crew inhabits the complex for one year to perform build-up, testing and some first research, the need would be for 19 t of supplies, including 6.5 t of propellant, which could be brought up, for example, in four Progress transporters in addition to the payload mass carried in the modules. This supply capability has already been demonstrated by the Soviets.

Table 3: Masses Delivered to Salyut and Back to Earth.

Salyut Equipment Delivered:	
Propellant	16 043 kg
Air supplies	2 806 kg
Consumables including food and water	22 145 kg
Spares	4 111 kg
Scientific equipment	1 616 kg
Film and photo equipment	392 kg
Furnishings	232 kg
Diversae	1 045 kg
TOTAL	48 390 kg
Equipment without Propellant: 32 347 kg	
Progress 1 – 23, 1250 kg each	28 750 kg
Cosmos 1443	3 000 kg
Soyuz 26 – 40 (w/o Soyuz 33), 25 kg each	350 kg
Soyuz-T 1 – 12 (w/o Soyuz-T 1, 8), 25 kg each	350 kg
Total Equipment without Propellant	32 350 kg
Propellant: 16 043 kg	
Progress 1 – 23 (w/o Progress 3, 20), 670 kg each	14 070 kg
Cosmos 1267, 1443, 1000 kg each	2 000 kg
Total Propellant	16 070 kg

Salyut Equipment Recovered:	
Exposed photos and motion picture films	501 kg
Magnetic record tapes	65 kg
Medical/biological samples	137 kg
Technological samples (processed material)	152 kg
Diversae (souvenirs etc)	332 kg
TOTAL	1187 kg
Soyuz 26 – 40 (w/o Soyuz 32, 33), 29 kg each	377 kg
Soyuz 32	180 kg
Soyuz-T 1 – 12 (w/o Soyuz-T 1, 8), 29 kg each	290 kg
Cosmos 1443	350 kg
Total	1197 kg
Supply per Cosmonaut per Day:	
Consumables including food and water	7.23 kg
Air supplies	0.92 kg
Equipment for experiments, film etc	2.41 kg
Propellant	5.23 kg
TOTAL	15.79 kg



The Cosmos 1686 – Salyut 7 – Soyuz T-14 complex (October 1985)

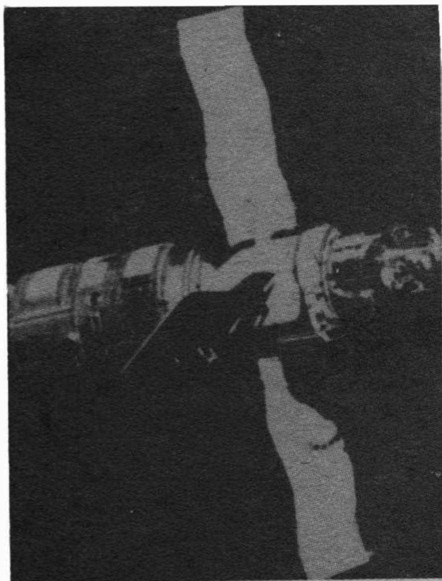
The two cosmonauts, Kizim and Solovyov, who manned the Mir station for a total of 71 days in two periods, returned to Earth on July 16 leaving the station unmanned. No crew exchange was performed as in the case of Soyuz-T 13 and Soyuz-T 14. It is reported that the first scientific module to be attached to Mir will be launched 'not before the end of the year' [5]. A new crew can be expected to settle in Mir early in 1987.

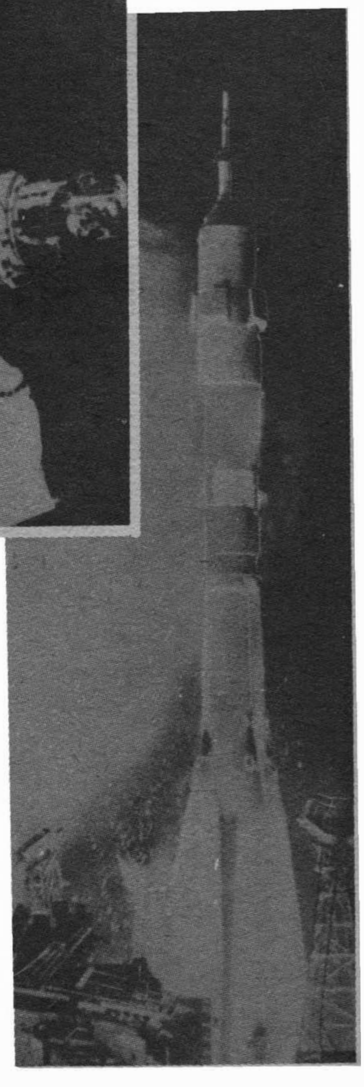
More details of the various vehicles to be used in the Mir programme can be found in Reference 12.

The Soviet manned space programme is expected to see a change in the role of the cosmonaut in order to increase his cost-effectiveness in space. As shown above, the supply requirements of Salyut crews (at 13.4 kg per day) have greatly exceeded those of the experimental work carried out (2.4 kg per day). The introduction over the next few years of increased automation and robotics should extend the range of experimental operations that can be handled by the same number of crew members.

References

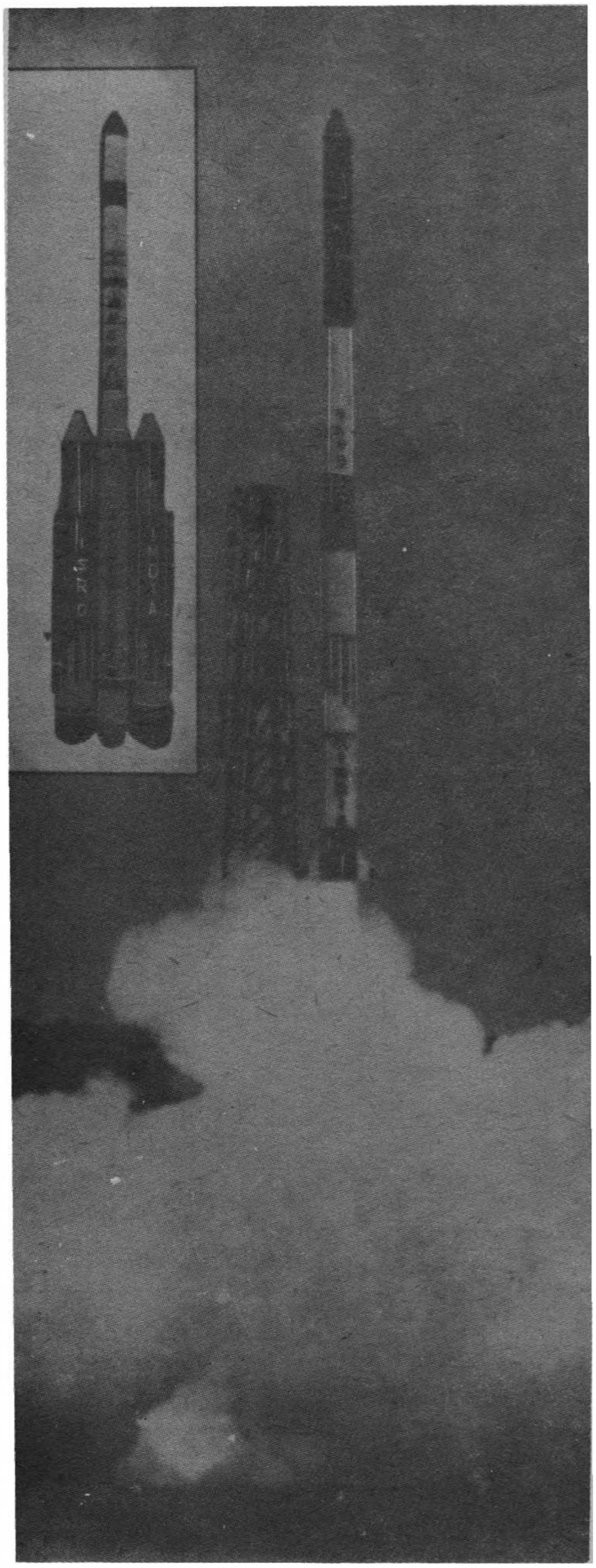
1. H.O. Ruppe et. al., "Memorandum – Betr. Rückkehrfähige Raumtransportersysteme für Europa", Technical University Munich, Aerospace Department, RT-TB 85/12.
2. P.S. Clark, R.F. Gibbons, "The Evolution of the Soyuz Programme", JBIS Vol. 36 No. 10, October 1983, p. 450.
3. D. Haeseler, "Soviet Space Hardware", JBIS Vol. 36 No. 10, October 1983, pp. 463-467.
4. P.S. Clark, "Soviet Spacecraft Masses for Earth Orbital Programmes", JBIS Vol. 38 No. 1, January 1985, p. 23.
5. "Salyut Missions Continue", Flight International, 14 June 1986, p. 44.
6. N. Kidger, "Salyut Mission Report", ***Spaceflight*** Vol. 26 No. 3, March 1984, pp. 137-140.
7. "Salyut 6 – Soyuz – Progress, Rabota Na Orbite", Mashynostroenye Press, Moskow, 1983, p. 36 (in Russian).
8. S. Berg, "Cosmos 1686 lance 8 t de charge utile", Air et Cosmos No. 1068, 2 November, 1985.
9. "Progress Launch Vehicles", Space Calendar Vol. 3 No. 43, 29 October – 4 November, 1984, p. 7. An apparent misprint has been corrected: Air supplies delivered to Salyut should read 2806 kg instead of 806 kg, giving the total of 48 390 kg, thus 0.9 kg per person per day.
10. Neues Deutschland, East-Berlin, 12 April 1986, p. 9.
11. P. Langereux, "La nouvelle station sovietique", Air et Cosmos No. 1069, 9 November 1985, pp. 59-60.
12. D. Haeseler, "Design Features of the Mir Space Station", ***Spaceflight***, Vol. 28 No. 11, November 1986, p. 384.





The launch of Soyuz T-6 on 24 June 1982 which carried one French and two Soviet cosmonauts to the Salyut 7 Space Station shown in the picture above.

INDIA —The Way Forward

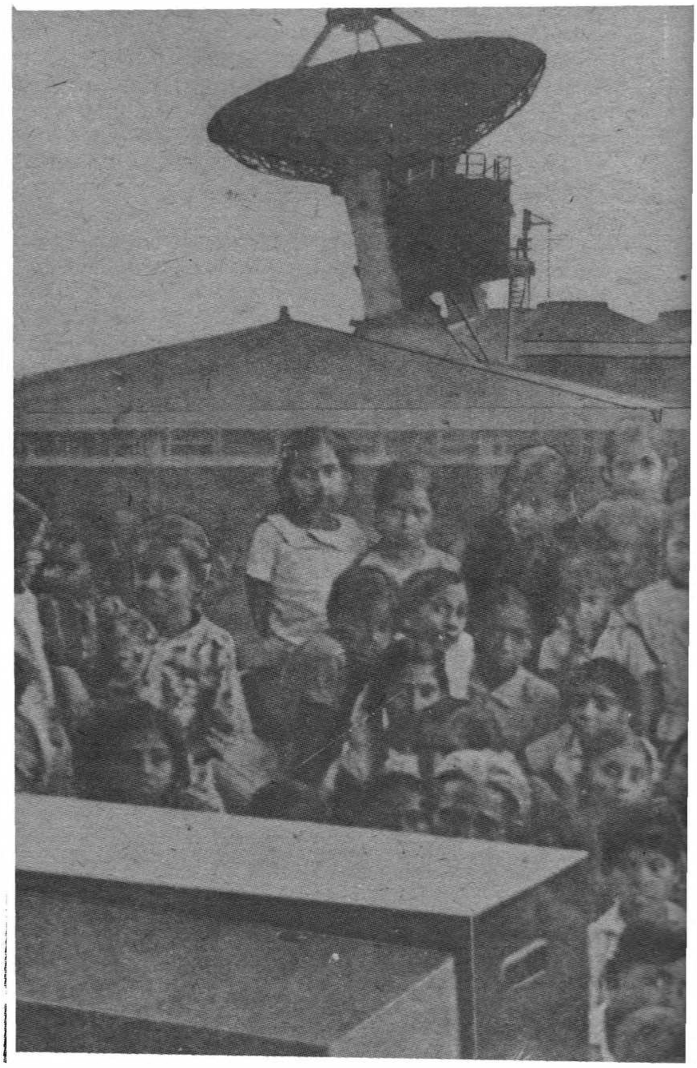


Economic divisions between developing and advanced industrial nations are immense and ever widening. Developing countries struggle to meet basic needs, while industrialised ones reap the rewards of their new technologies. Bridging the gap is one of the world's major problems.

India is now investing heavily in Space as a way to bridge the gap – by leapfrogging into high technology. A programme of Space applications for advancing communications and education throughout its village communities is already underway.

Left: Lift-off of an SLV-3. The inset picture shows the Augmented Satellite Launch Vehicle (ASLV).

Below: TV is brought to villages for community viewing by INSAT-1. In the background of this composite picture is the INSAT-1 Master Control Facility which controls and manages the satellites during their orbit-raising and on-orbit phases.



The Satellite Control Centre at the INSAT Master Control Facility at Hassan, Karnataka.

In 1980 India achieved its first successful satellite launch and has since embarked on an impressive 10-year plan of launcher development. The aim is to develop a launch capability for placing INSAT-II communications satellites in geostationary orbit in the 1990's.

The present INSAT-I (Indian National Satellite System) is a communications satellite system that became operational in 1983 when INSAT-IB was orbited and stationed over India at longitude 74°E. This spacecraft has extended TV coverage to 70 per cent of India's population and should be operational for seven years. Ground-based TV receiving dishes have been installed at thousands of India's many villages and supply these communities with educational and social programmes plus weather reports and local weather alerts.

India has benefited from cooperation with both the US and USSR. An Indian Cosmonaut flew in the successful 7-day Soyuz T-11/Salyut 7 mission in 1984. An Indian astronaut was due to have flown in September 1986 in the Shuttle Orbiter Challenger from which India's second communications satellite INSAT-IC would have been released. With the postponement of the Shuttle programme, this spacecraft is now scheduled for launch by Ariane V26 in January 1988. INSAT-ID is scheduled for a Shuttle launch in October 1990.

India is also developing remote sensing satellites to support its work on the surveying of natural resources. In 1987, it will be paying for its first such satellite, IRS-IA, to be launched by the Soviet Union, thereby marking the entry of the USSR into the commercial satellite payload market.

For 1988, India is planning to host the annual congress of the International Astronautical Federation at Bangalore where an important part of its space organisation is located.

INDIA'S SPACE CENTRES

The setting up of a small sounding rocket facility at Thumba near Trivandrum, called the Thumba Equatorial Rocket Launching Station (TERLS), in 1963 marked the beginning of India's attempts at practical exploration of space for meeting various national needs such as rapid development of mass communication and education, and timely survey and management of the country's natural resources.

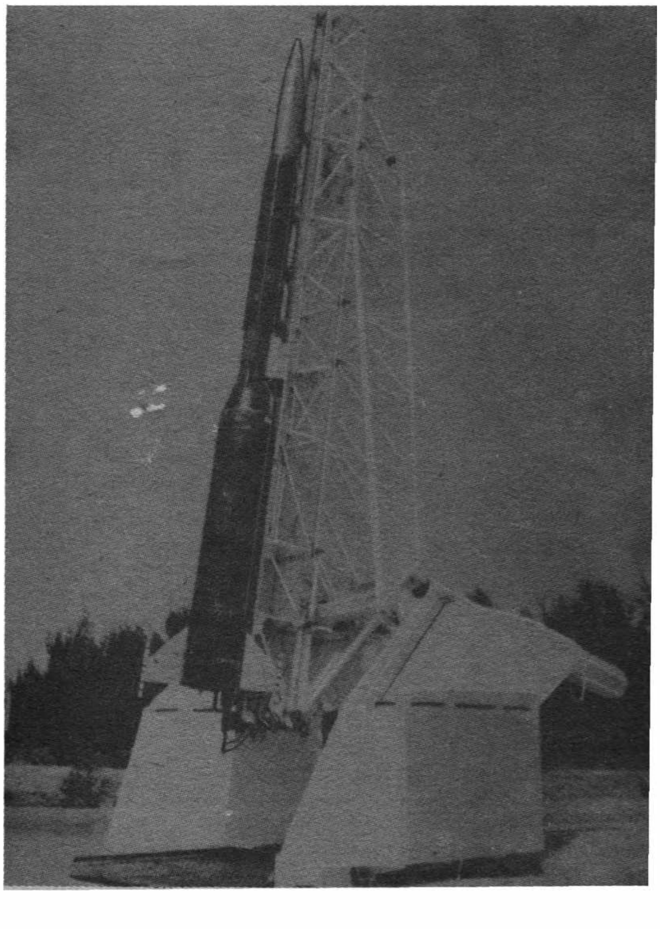
TERLS, established with foreign assistance for conducting rocket experiments for meteorological and upper atmospheric investigation, was dedicated to the United Nations as an international sounding rocket range in 1968.

From this modest beginning, Indian space scientists soon started work on developing, sounding rockets, satellites and satellite launch vehicles for their experiments. The growth of the Indian space programme over the past two decades since the inception of TERLS has been progressive.

Introduction

India's space programme was formally organised in 1972 when the Government set up the Space Commission with a view to promote the development and application of space technology and space sciences for the socio-economic benefit of the nation. Responsibilities of the Commission include the formulation of the policy of the Department of Space for the consideration of the Prime Minister, preparation of the budget of the Department of Space for the approval of the Government and implementation of the Government's policy in all matters concerning outer space.

The RH-560, largest of the Rohini Sounding Rockets and capable of reaching 350 km with a 100 kg payload.



The Department of Space (DOS) is responsible for the execution of activities in Space Applications, Space Technology and Space Sciences through the Indian Space Research Organisation (ISRO).

The headquarters of both DOS and ISRO, located at Bangalore, provide overall direction to the technical, scientific and administrative functions of the ISRO centres which have a combined strength of over 12,000 personnel.

DOS Establishments

These may be located on the map of India on paged 434-5.

Vikram Sarabhai Space Centre (VSSC), named after the founder of India's space programme, is the main centre for research and development in space technology namely sounding rockets and satellite launch vehicles. India's first Satellite Launch Vehicle, SLV-3, was designed and developed here. VSSC is at present engaged in the development of the Rohini series of sounding rockets and advanced satellite launch vehicles like the ASLV and PSLV; and the operation and maintenance of the UN-sponsored Thumba Equatorial Rocket Launching Station (TERLS).

ISRO Satellite Centre (ISAC), conducts research and development in Satellite Technology. Aryabhata, the first Indian Satellite, Bhaskara-1 & 11, Rohini and APPLE Satellites were designed and built at ISAC. Spacecraft of the Indian Remote Sensing Satellite (IRS) series and Stretched Rohini Satellite Series (SROSS) are being designed and fabricated at ISAC.

SHAR Centre, has facilities for launching large multistage sounding rockets and satellite launch vehicles – SLV-3 vehicles were launched from here. It is the main ground station for the control of satellites and has facilities for static testing of launch vehicle stages and large scale production of rocket propellants. propellants.

Space Applications Centre (SAC), is the main centre for activities relating to applications of space science and technology for practical uses such as telecommunication; TV broadcasting and reception via satellite; survey of natural and renewable Earth resources from space/air platforms using remote sensing techniques; and studies in space meteorology and satellite goedesy

Auxiliary Propulsion System Unit (APSU), with its laboratories at Bangalore and Trivandrum has primary responsibility for designing, developing and supplying the propulsion control packages for ISRO's launch vehicles and satellites. The work related to launch vehicle propulsion control is done at Trivandrum while the activities in spacecraft propulsion and pressure transducer production are carried out at Bangalore

Development and Educational Communication Unit (DECU), is responsible for the production of developmental and educational TV programmes, related research, training, etc.

ISRO Telemetry, Tracking and Command Network (ISTRAC), with its headquarters at Bangalore, consists of

a network of five ground stations located at Sriharikota, Ahmedabad, Car Nicobar, Trivandrum and Kavalur.

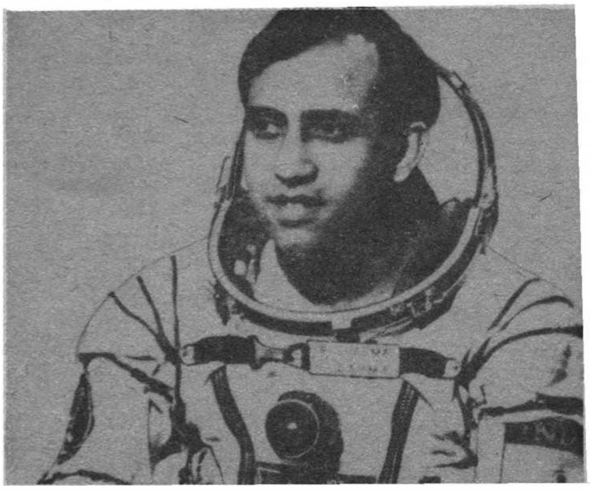
National Remote Sensing Agency (NRSA), functions as an autonomous registered society under the Department of Space for utilising the potential of remote sensing technology in the survey of natural resources. Important activities of NRSA include operations of the Landsat Ground Station, the Research Flight Facility at Hyderabad and the Indian Institute of Remote Sensing at Dehradun

Physical Research Laboratory (PRL), supported by the Department of Space, it looks after research programmes in space sciences and extends administrative support to the Udaipur Solar Observatory.

INSAT-1 Space Segment Project Office (INSAT-1 SSPO). The responsibilities of the Department of Space for the implementation and operation of the INSAT-1 space segment are carried out by the INSAT-1 SSPO and the INSAT-1 Master Control Facility (MCF), respectively. MCF forms the major element of the ground-segment employed to support the operations of the INSAT satellite after its separation from the launch vehicle. MCF situated in the Hassan District of Karnataka was commissioned in early 1982.

Research Sponsored by ISRO

Since 1976, ISRO has been supporting research and development in the universities under its RESPOND Programme. ISRO support mainly relates to basic research and development aspects of space science, technology and applications relevant to the Indian Space Programme.



Rakesh Sharma, India's first cosmonaut, who flew to Salyut 7 in April 1984.

The primary activity under RESPOND involves initiation of proposals, their evaluation based on scientific and technical merit, and approval/funding of the schemes after selection by ISRO. The progress made by each project is monitored by ISRO scientists/engineers and progress reviewed on an annual basis.

In addition to providing financial grants for the appointment of research and support staff, purchase of special equipment and other operational expenses, ISRO's own facilities are made available to principal investigators. So far, over 160 R&D projects have been supported of which more than 70 have been completed.

Launch Vehicle Developments

by H.P. Mama

India plans to launch an indigenously designed and fabricated satellite with its own launch vehicles once every 12 to 15 months during the remainder of this decade. The next launch from the Sriharikota Launching Range (SHAR) in the state of Anohra Pradesh will be of the first 30-tonne, 23.5 m long Augmented Satellite Launch Vehicle (ASLV-D-1), which is based on the earlier SLV-3, and has two zero-stage strap-on boosters of the same type.

ASLV Launches

In November 1985 a successful flight test was undertaken of the strap-on rocket technology. For the test, a Rohini RH-300 sounding rocket formed the core vehicle, while two RH-200s formed the strap-on boosters. All test objectives including the simultaneous ignition of the two strap-on motors, their separation, and flight mechanics of all three motors were satisfactorily met.

ASLV-D-1 will carry a 150 kg Stretched Rohini Satellite Series (SROSS-1) satellite into a near-Earth (150-300 km) orbit, on a technological mission to establish launch vehicle characteristics and performance of the satellite's main systems.

Only a limited number of ASLV launches are planned and among their functions will be to develop and qualify a number of indigenous technologies and subsystems for the Polar Satellite Launch Vehicle (PSLV). The PSLV will be able to place 1,000 kg-class satellites, such as the Indian Remote Sensing Satellite (IRS) into a 900 km Sun-synchronous polar orbit, at the rate of one every 26 to 30 months. The first IRS is to be launched next year from the Soviet Union, with the first PSLV-launching scheduled for 1988/9.

PSLV Technology

PSLV is a four-stage launch vehicle with a lift-off weight of 275 tonnes, overall height of 44.1 m and a maximum diameter of 2.8 m. Total project cost for PSLV, including the new ground facilities being set up, is Rs 3,500 million. Each launch vehicle is expected to cost Rs 350 million.

PSLV's PS-1 first stage has been described as the third-largest solid propellant rocket motor in the world. Rather than invest in very large casting facilities, it was decided to produce multi-segment charges, with each segment of comparatively small size. PSLV's five-segment first-stage motor is fabricated by a private sector Bombay-based engineering company, Larsen & Toubro, from M250 maraging steel. It was selected as it offers exceptionally high strength after heat treatment.

Maraging steel is now produced in India by Mishra Dhatu Nigam (MIDHANI), a Defence Public Sector Organisation, in the form of blooms, ingots and slabs. The Rourkela Steel Plant will roll the slabs into large plates, while the Welding Research Institute at Tiruchi has developed the required welding technology. Trial segment fabrication was undertaken by Bharat Heavy Electricals Ltd (BHEL) before Larsen & Toubro took over full-scale industrial production.

The five 2.8 m diameter segments each have 25 tonnes of a very high energy Hydroxyl-terminated Polybutadiene (HTPB) solid propellant – the most energetic formulation yet developed in India. Production of HTPB is to be entrusted to industry and casting will be undertaken at the Solid Propellant Space Booster Plant (SPROB). Oxidiser for the propellant is to be produced at the 160 tonne capacity Ammonium Perchlorate Experimental Plant (APEP) at Alwaye. With each first stage costing about Rs. 40 million, ISRO is considering parachute-borne recovery from the sea off Sriharikota.

Six solid-propellant strap-on boosters (designated zero-stage) to be mounted at the base of the PS-1 stage, have been developed from the first stage of the SLV-3. These can be ignited at launch or in flight, and in any desired combination.

Thrust vector control for the PSLV PS-1 stage is by secondary fluid injection, from two large tanks mounted alongside the six zero-stage boosters.

Two of the four stages – second and fourth – will have storable high-energy liquid-propellant combinations – The second stage will have UDMH and nitrogen tetroxide. UDMH is being produced at Indian Drugs and Pharmaceuticals Ltd and production of nitrogen tetroxide is already under way at Hindustan Organic Chemicals Ltd, Rasayani. With the rapid build-up of India's industrial capability, The Indian Space Research Organisation (ISRO) is gradually withdrawing from manufacturing and concentrating on R&D and design work.

The second stage (PS-2) has a single gimbal-mounted improved SEP Viking rocket engine – the only major componet to be licence-produced for PSLV. On the other hand, the fourth stage (PS-4) (designated the Liquid Upper Stage or LUS) will have two long-burning 7 kN thrust pressure-fed liquid propellant units operating on a MMH and nitrogen tetroxide combination. The LUS thrust chambers are noted for their niobium nozzle extensions, carbon-carbon nozzle divergent sections and propellant tanks of titanium alloy. These units are also to be used for PS-1 roll control.

A lightweight polyaramid fibre case and a very high energy solid propellant formulation characterise the SP-3 stage.

On the point of high-energy solid propellants, ISRO recently obtained global patients for a castor oil based polyol. It was formulated by scientists at the Polymer & Special Chemicals Division of the Vikram Sarabhai Space Centre (VSSC) at Thumba. Worldwide, polyols are petroleum derivatives. The VSSC technology used castor oil as the starting material as India is the second-largest producer of castor oil in the world. The new high-energy propellant has already been flight-tested in an Advanced Rohini RH-300 rocket.

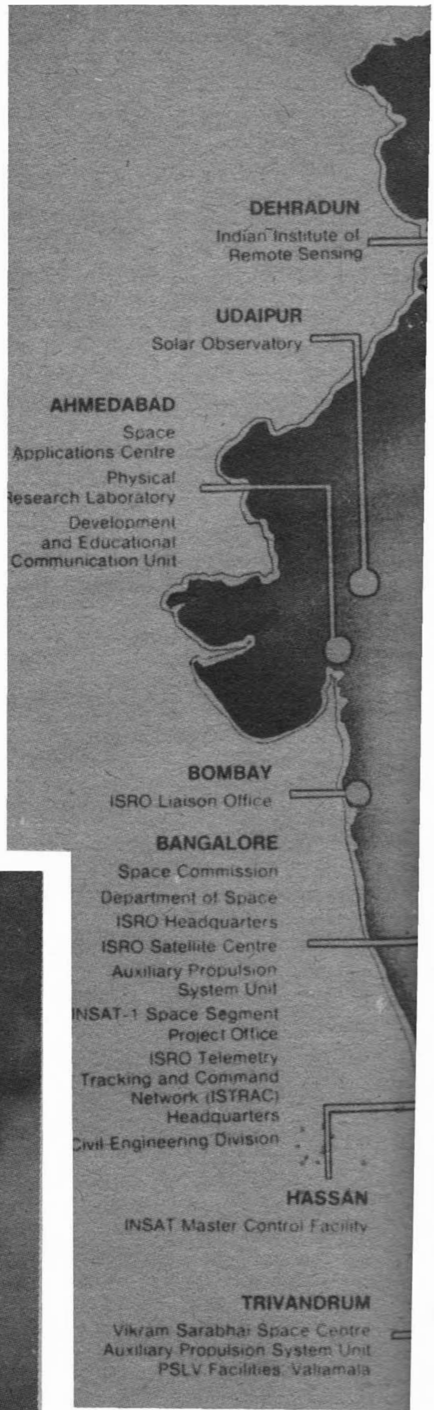
Initial performance figures for the PSLV were: PS-1 400 tonnes thrust for about 90 sec; PS-2 74 tonnes thrust for 145 sec; and PS-4 1,400 kg thrust for 430 sec.

New Test Facilities

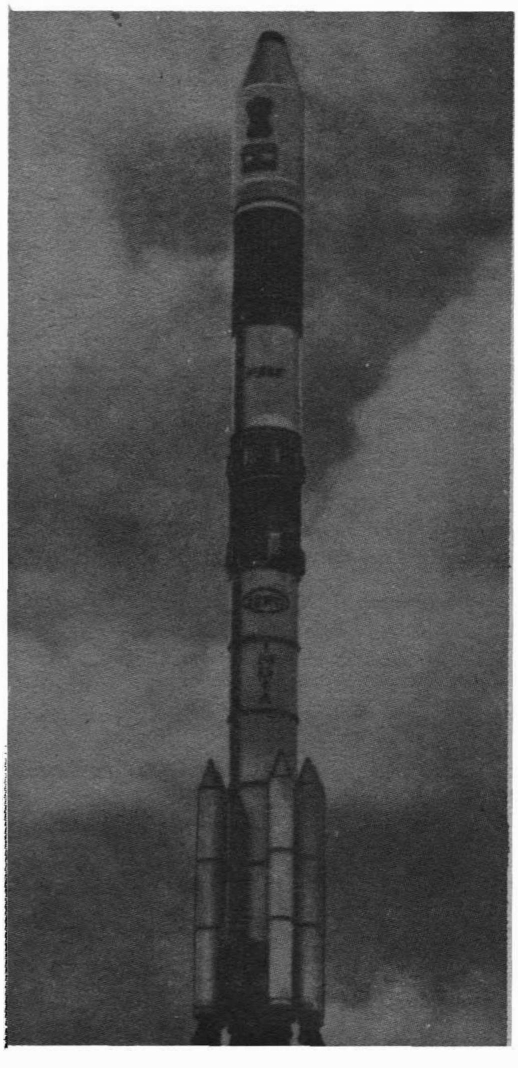
Existing facilities at the VSSC were totally inadequate for PSLV and two new complexes were set up for the vehicle. Of these, the Rs. 280 million facility at Valiamala (meaning Big Hill) covers an 80 hectar site among picturesque hills, 25 km from Trivandrum and has about 700 personnel. It has 22,500 sq m of built-up area and four km of internal roads. Various subsystems of PSLV will be developed, tested and integrated at site.

Located at Manendragiri, about 100 km from Trivandrum, is the new Liquid Propulsion Test Facility for test firing large liquid-propellant rocket engines, starting with the Viking.

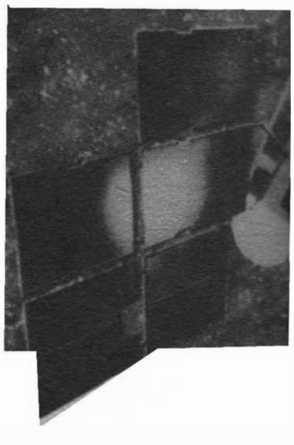
Beyond the PSLV, ISRO already has announced plans for the GSLV to place India's 1,200 kg INSAT II communications satellites into geostationary orbits in the 1990s. That launch vehicle will have a cryogenic (liquid hydrogen/ liquid oxygen) fourth stage. India will then have entered the launch vehicle "big league."

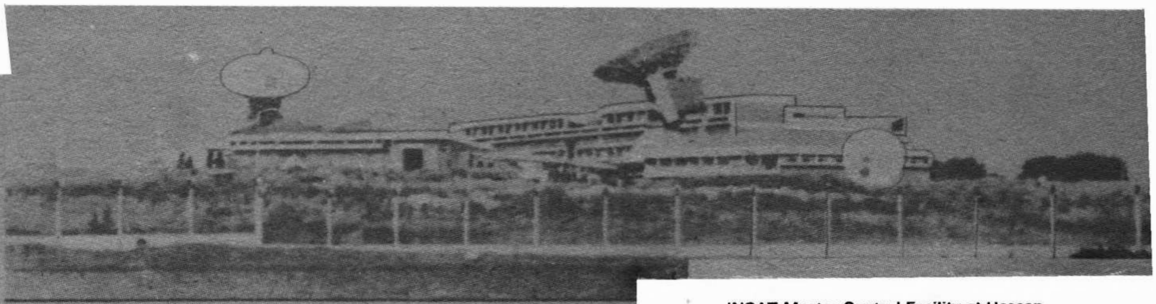


PSLV launch vehicle.

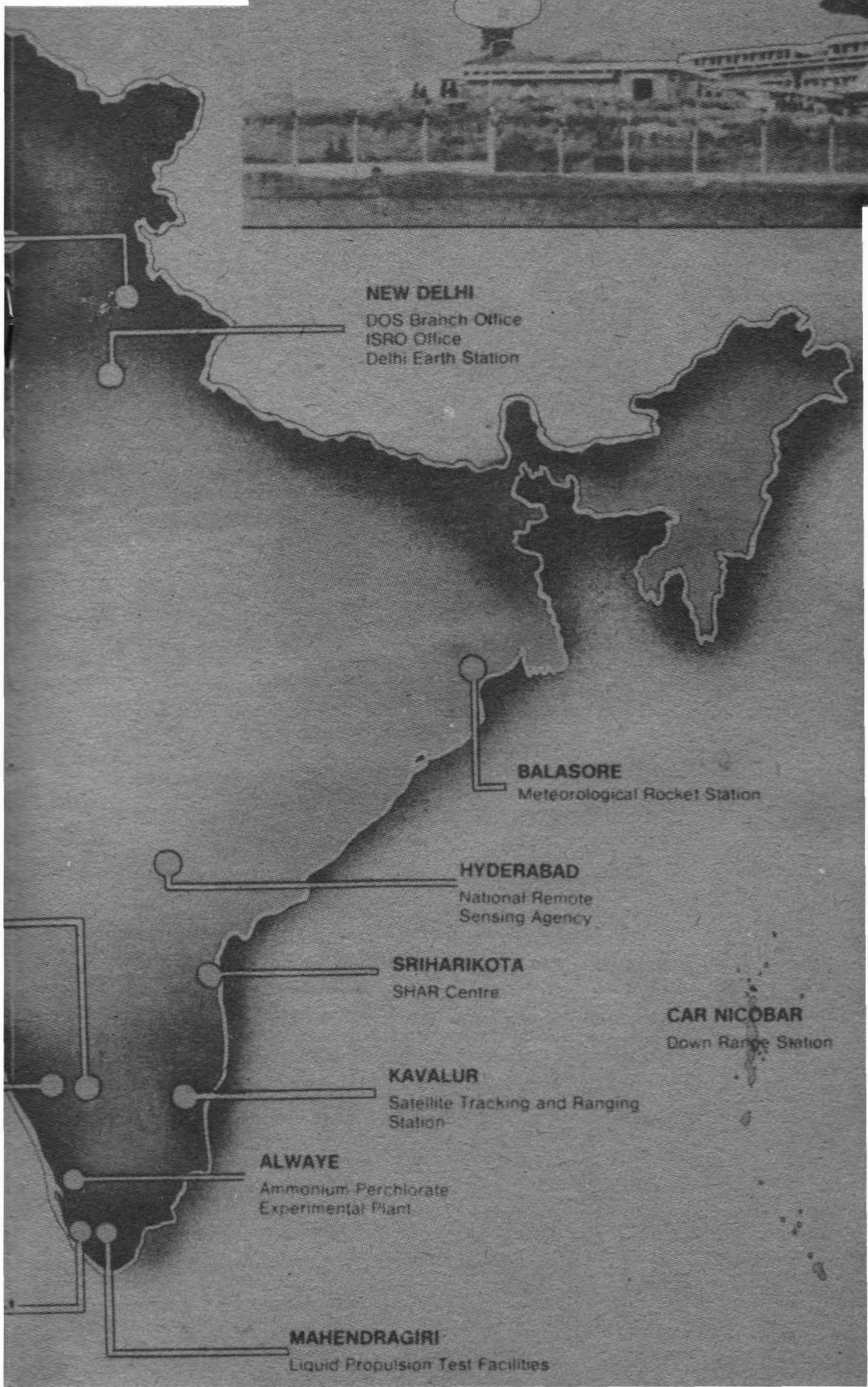


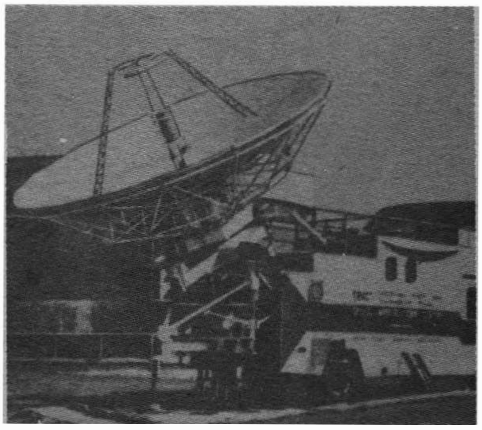
Insat 1.



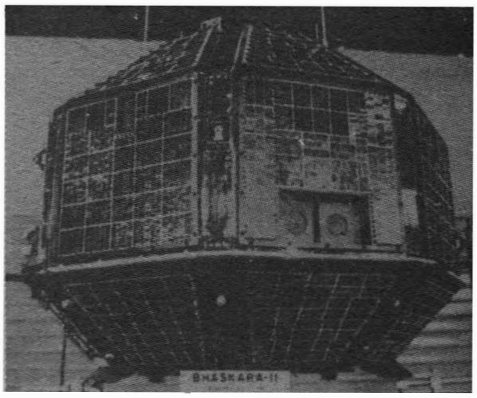


INSAT Master Control Facility at Hassan.

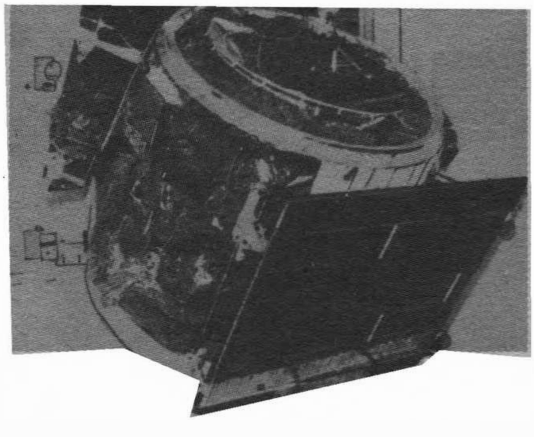




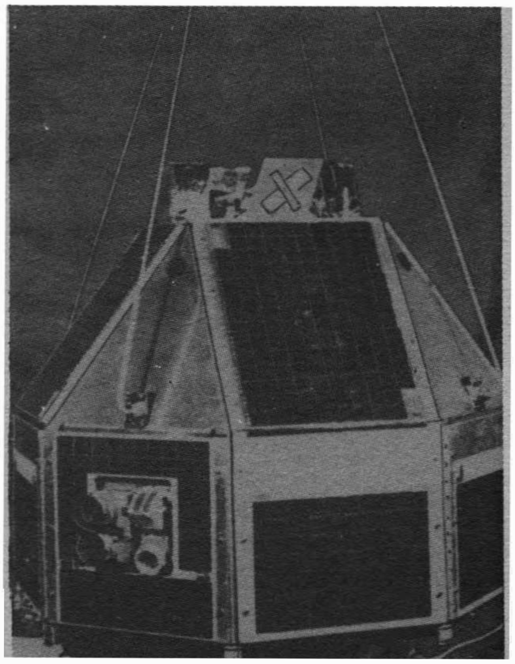
A mobile communications dish.



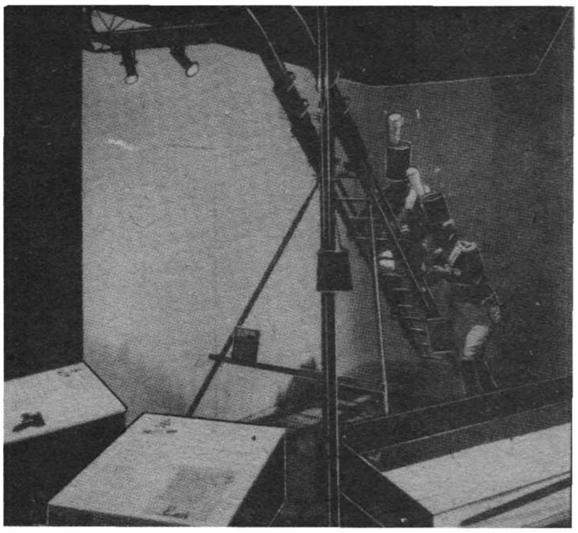
RS-D2 Satellite.



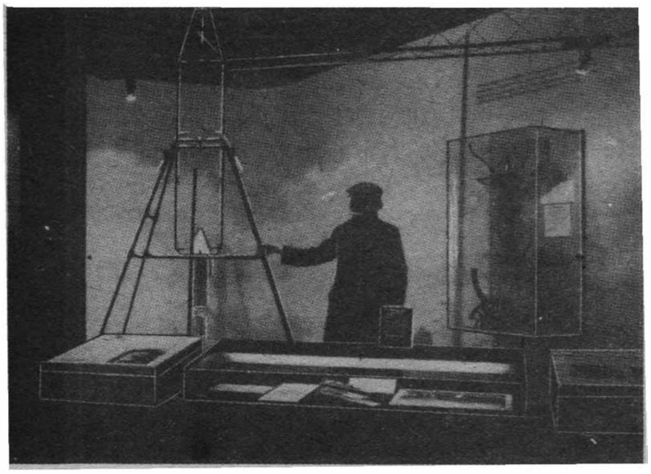
Ariane Passenger Payload Experiment (Apple) satellite.



Duke of Kent Opens Space Gallery



A full-size model of Sir William Congreve's rocket launcher (1806).



American scientist Robert Goddard launched the first successful liquid-fuel rocket in March 1926.

A bold initiative to give the UK public a better understanding and closer appreciation of the world of space flight and technology is proving a huge success.

In its first six weeks the new Space Gallery at the Science Museum, London, has attracted wide interest from thousands of visitors.

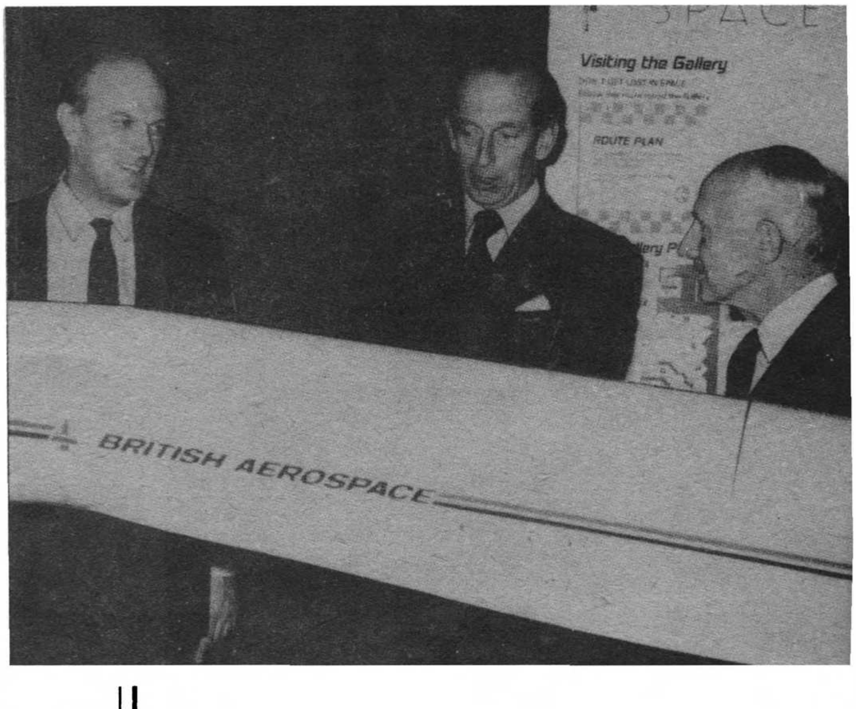
The Gallery, officially opened by HRH the Duke of Kent on October 21, covers 1400 square metres on two levels in its portrayal of the historical development of space flight from the earliest Chinese gunpowder rocket dating from 1000 AD to the age of US and Soviet space stations.

The display is divided into eight main sections which include rocket technology and applications, Britain and Europe in space, satellite technology and the problems of living in space.

Rockets and satellites from the Science Museum's space technology collection, along with many items of hardware lent by other organisations including NASA, form the nucleus of the gallery. The American Scout rocket, 23 m in length hangs from the ceiling above the central aisle, and looks down on the Apollo 10 command module that journeyed round the Moon in 1969 and is on loan to the Museum from the National Air and Space Museum, Washington.

Visitors can also see Skylark, Britain's most successful rocket and Black Arrow, Britain's first and only satellite launcher. Looming overhead in another

HRH The Duke of Kent (centre) with museum director Dr. Neil Cussons (left) and Sir Austin Pearce, Chairman of the Museum's Trustees, discuss the Hotol spaceplane following the official opening.

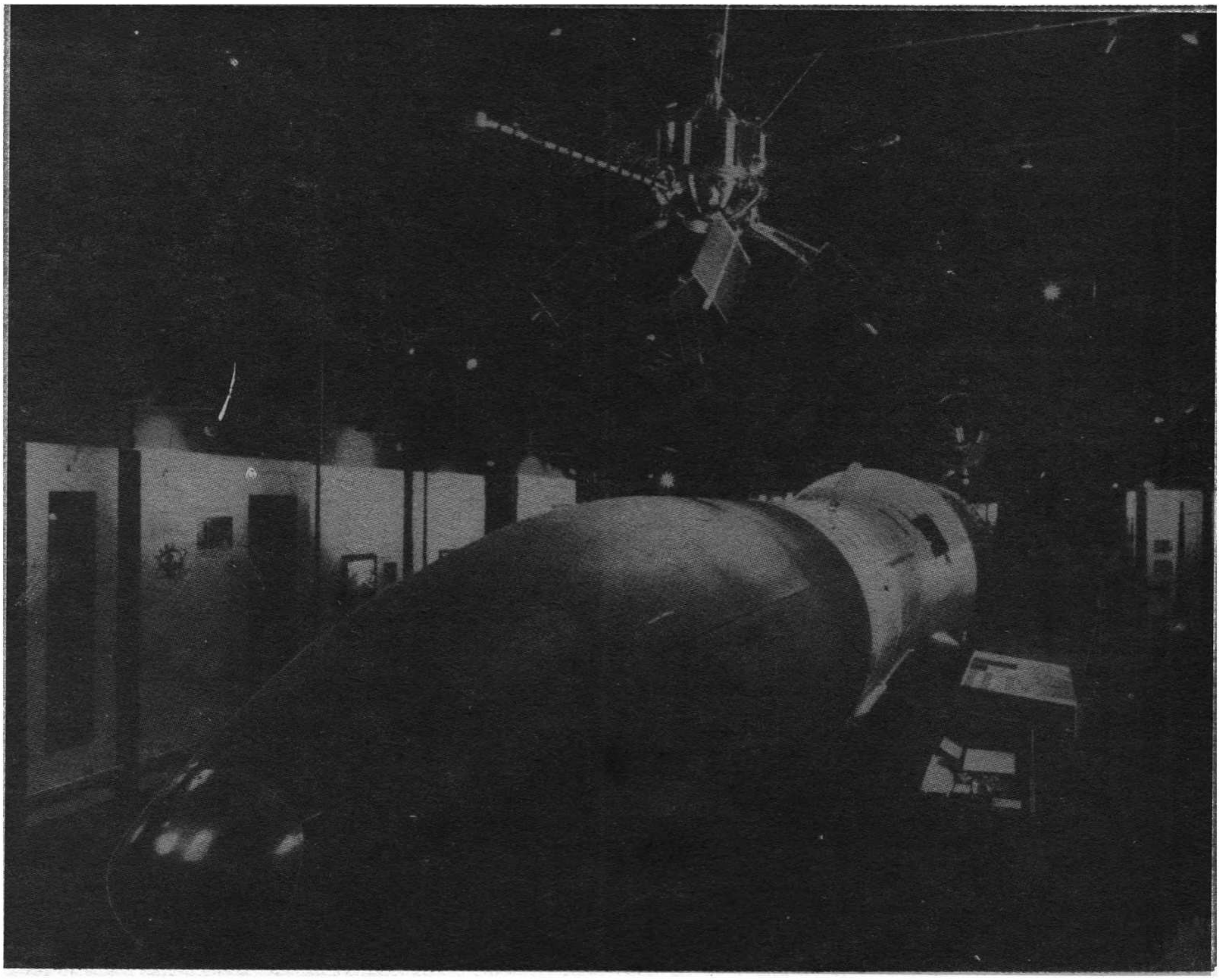


Gallery Guests

British Interplanetary Society representatives Len Carter (Executive Secretary) and Shirley Jones (Assistant Executive Secretary) were among the guests of honour at the opening ceremony performed by HRH the Duke of Kent on October 21.

Other guests included many distinguished figures from industry, including Mr. Andrew Glasgow, Managing Director of Marconi Space and Defence Systems, Mr. Ray Munday, a former Chairman of the United Kingdom Industrial Space Committee (UKISC), Mr. Peter Conchie, a Director of British Aerospace, representatives of the British National Space Centre and the former UK candidate astronauts.

Representatives from overseas included Mr. James C. Welch, director of the Hubble Space Telescope Development Division for NASA's Office of Space Science and Applications.



The British-built Black Arrow rocket features prominently in the Britain and Europe in Space display.

section of the gallery is the V2, the scourge of London during World War II. This is probably the most complete in existence and was assembled from sections captured at the end of the war.

The Space Gallery is dominated by a full scale model of the Apollo Lunar Lander and there are also scale models of the Space Shuttle, the Hubble Space Telescope (which is the subject of a special feature beginning on page 440), the Viking Mars lander and other satellites.

Audio visual and interactive displays are used to the full and snippets of early films include a rare colour film of a V2 launch. One of the interactive displays is 'Globetrotter' which uses Landsat images covering the greater London area. By touching a screen visitors zoom-in on selected areas and see for example a football pitch – all this from a satellite orbiting 700 km above the Earth.

Dr. John Becklake, one of the museum curators, explained that the concept for the new gallery grew out of the need to answer the basic questions: what are satellites and rockets? What do they do? And, how do they work?

"Our aim is to try and demistify the concept of Space. We wanted to get away from the impression that Space is just for the brilliant few. Space is for everyone – it is just another technology," he said.

The Museum's space collection goes back more than a decade but this is the first time that all the exhibits have been brought together under one roof.

Looking at Earth

***Jim Sweeney** reviews a new exhibition at the National Air and Space Museum in the United States.*

In the United States, one of the most popular posters of the 1970s depicted the view of the Earth from the Moon, taken during one of the Apollo missions. Aviation and space flight have certainly opened up new ways of seeing our planet.

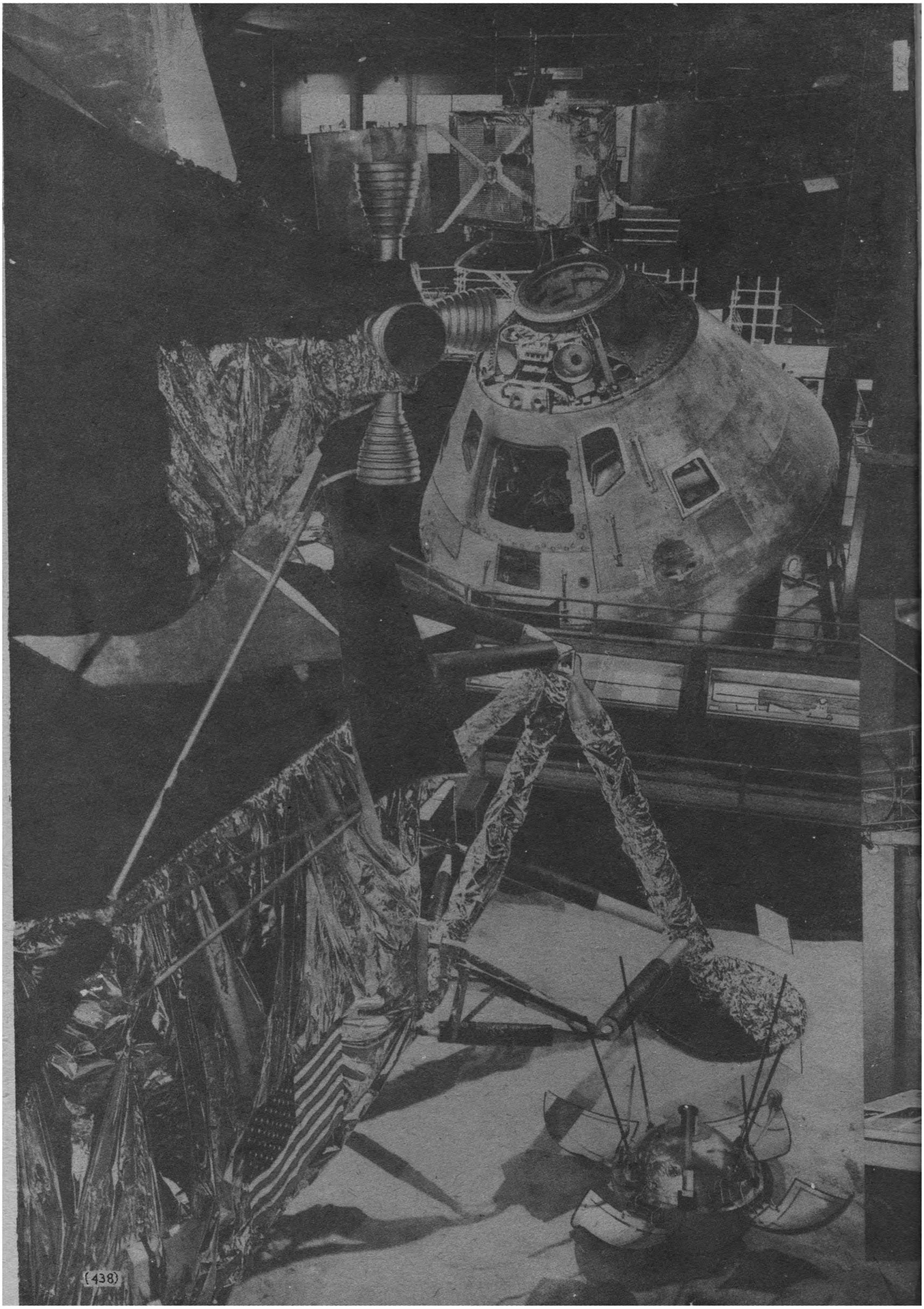
To underscore the importance of Earth observation, the Smithsonian Institution's National Air and Space Museum, Washington, has opened a new exhibition which reviews some of the early ways of viewing the Earth from above, such as cameras attached to pigeons and kites, through to modern satellite technology.

The Air and Space Museum has found ways to bring facts to life: film featuring the weatherman from one of the commercial television networks explains the importance of weather satellites and a video monitor shows a weather satellite view of the United States for the past 48 hours.

The exhibition stresses the varied uses of images from space, from using heat-measuring instruments to track a fire in an underground coal seam in Pennsylvania to the discovery of ancient river beds under the Sahara sand by radar on the Space Shuttle.

Another section uses a touch-sensitive screen to let visitors call up Landsat images of their home state.

The Air and Space Museum has also put up a new exhibit on Europe's Ariane. It includes a model of an Ariane launcher and a videotape showing operations at the Ariane launch site in Kourou, French Guinea.


(438)

The eight permanent exhibition sections are complemented by a special exhibitions area which will be used for a variety of topical displays. The present theme is space literature and in the future there are plans for displays ranging in scope from remote sensing and the Hotol spaceplane to Chinese and Japanese rocketry and space science.

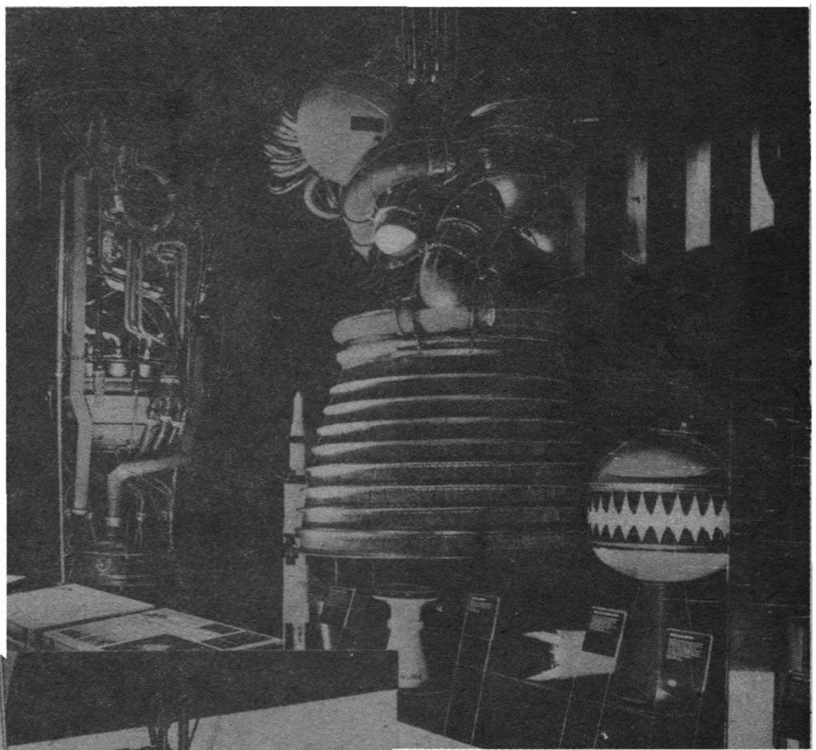
The Science Museum is open every Monday to Saturday (10 a.m. to 6 p.m.) and Sunday (2.30 a.m. to 6 p.m.), excluding some public holiday.

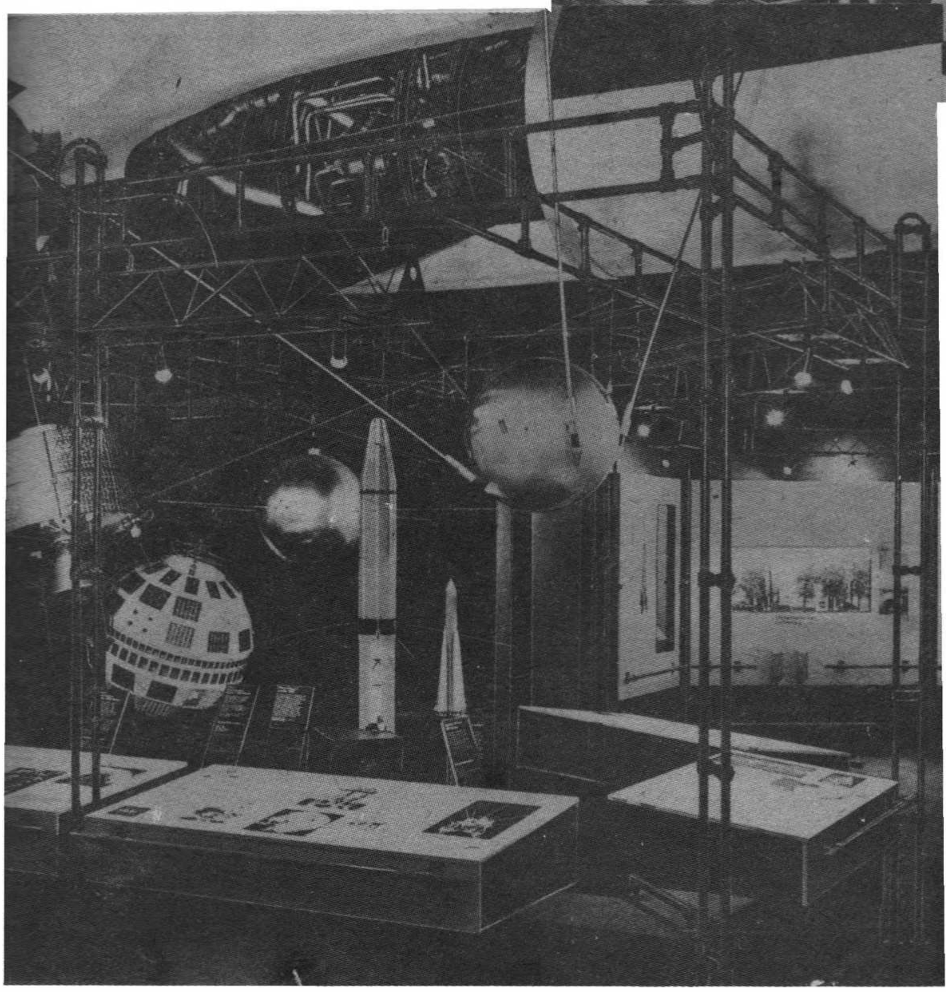
Main sponsors for the new Space Gallery are British Aerospace, Marconi Space Systems and the British National Space Centre. Museum director is Dr. Neil Cussons and those involved in the setting up of the new exhibition included Dr. John Becklake, Jon Darius, Dr. John Griffiths and Peter Turvey.

A model of the Lunar Module and the Apollo 10 Command Module Capsule dominate the Space Gallery as seen from the upper walkway.

Rocket motor display (right), including a Saturn V J2 engine.

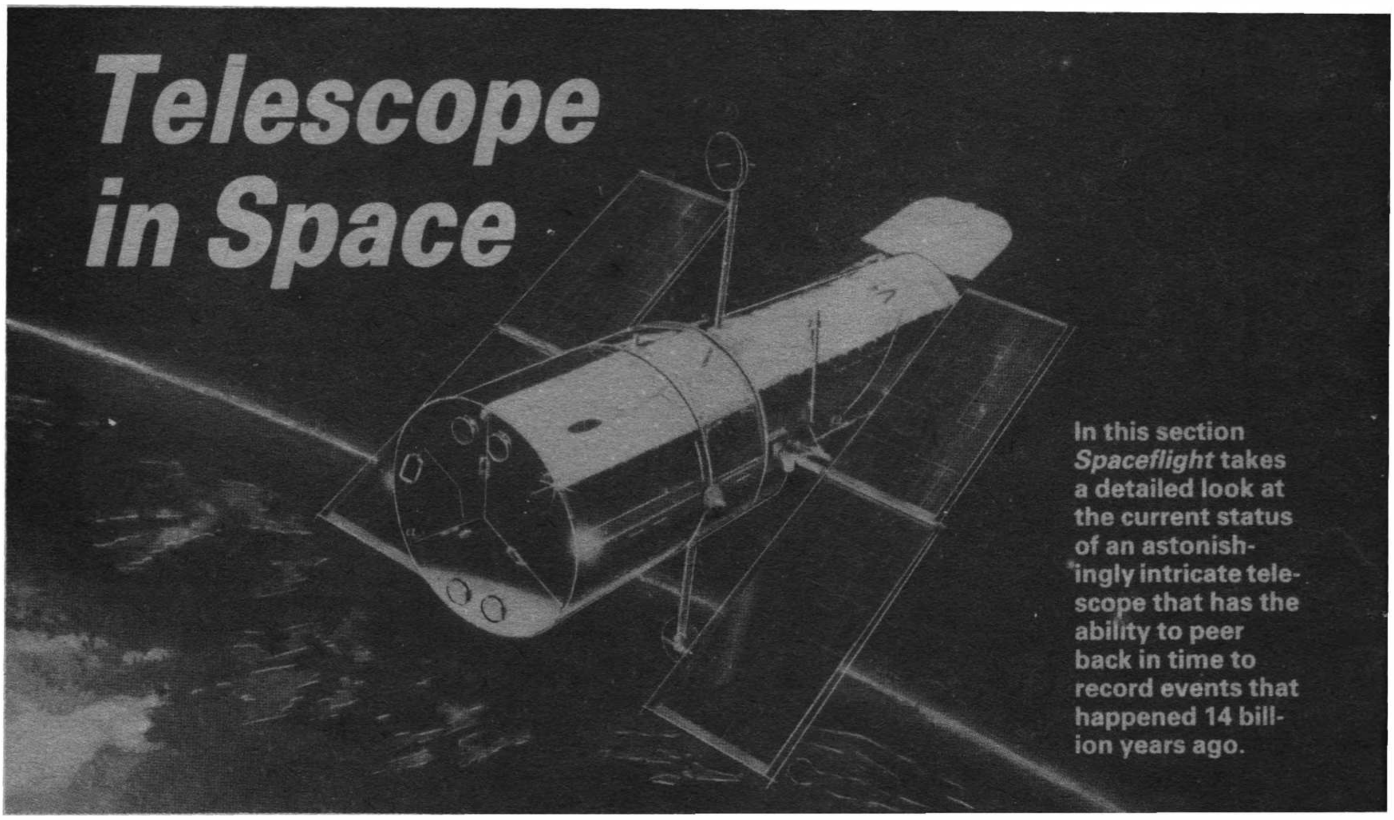
Sputnik, the world's first artificial satellite, and the V2 rocket are major features of the History of Spaceflight section.





SCIENCE MUSEUM

Telescope in Space



In this section *Spaceflight* takes a detailed look at the current status of an astonishingly intricate telescope that has the ability to peer back in time to record events that happened 14 billion years ago.

NASA is to operate a telescope in space that will be capable of observing celestial objects some 50 times fainter than hitherto, thereby extending the observable horizon out to distances of some 14 billion light-years from the two billion light-years of the largest ground-based instruments. The telescope has been named in honour of the American astronomer Edwin P. Hubble who made outstanding contributions to galactic astronomy and the structure of the universe during the first half of this century.

The mirror of the Hubble Space Telescope is 2.4 meters diameter and with its associated optics makes one of the largest and most precise astronomical instruments ever produced. When launched into orbit its performance will be greatly enhanced by its high vantage point above the atmosphere, 'seeing' conditions being near to perfect. A whole new range of ultraviolet wavelengths, that would otherwise be absorbed by the Earth's atmosphere, will be detectable.

But for the Challenger disaster and postponement of the Shuttle programme, the Hubble Space Telescope would by now be in orbit circling the Earth and being checked out before beginning 15 years of intensive observation.

Although the Hubble Space Telescope, or the HST for short, is only one of many Shuttle payloads that await launch, it warrants special recognition being the largest and most expensive space science project of all time. In contrast to other payloads, it is a 'one-off', no back-up being available in case of failure. Also, its dimensions exclude the use of other (expendable) vehicles for its launch – it is Shuttle-dependent.

Now scheduled for a 1988 launch, the HST will undoubtedly be the main highlight of the resumed Shuttle programme. Astronomers are looking forward to gathering new observations of a quality unimagined by their predecessors.

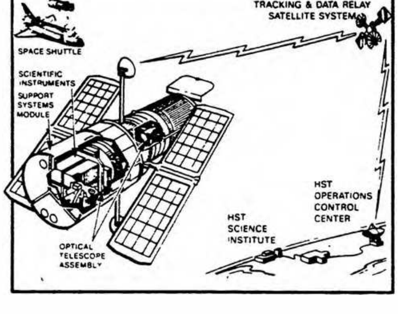
Communications Downlink

The HST will orbit the Earth at an altitude of about 350 nautical miles and an orbital inclination of 28.5 degrees while under command from the Space Telescope Operations Control Center at the NASA Goddard Space Flight Center.

Communications between the ground and low Earth orbit have traditionally been via Earth Stations around the world. Even with its present extensive network of stations, NASA can count on no more than 15 per cent coverage of a low orbit by this means. Long-standing plans call for the introduction of two operational geostationary satellites at longitudes of 41°W and 171°W (and one back-up satellite at 79°W). Routed via these satellites, ground to low-orbit communications can attain 85 per cent coverage.

The first such TDRSS (Tracking and Data Relay Satellite System) reached orbit in 1983, but the second one was a payload onboard the lost Challenger and the TDRSS system therefore remains incomplete.

HST communications via TDRSS.



When Shuttle launchings resume in 1988, a TDRSS payload has priority for the first resumed launch on February 18 (***Spaceflight***, November 1986, p.378). Communications to and from the HST will be via one or other of the two TDRSS's with a downlink to White Sands, New Mexico and thence to NASA Goddard Space Flight Center.

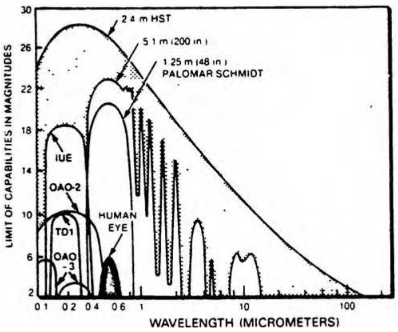
Atlantis Launch

After the first Shuttle of the resumed launch programme, the three following launches will carry two defence payloads and one back-up TDRSS. The next launch on November 17, 1988 will be Atlantis with the HST. The possibil-

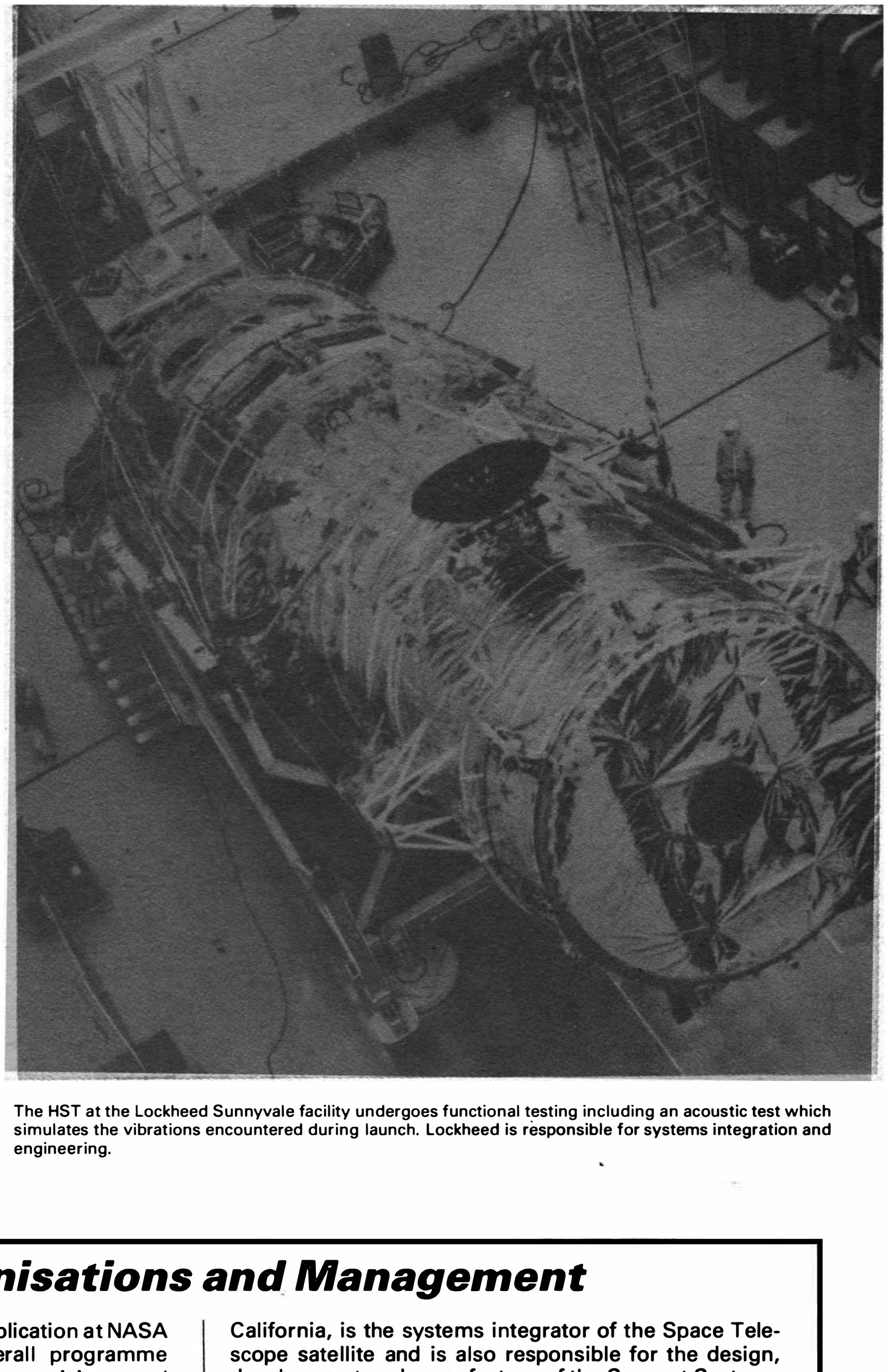
ity is currently being examined with the US Department of Defense of bringing forward the HST launch to the previous Atlantis flight on May 26, which at present is scheduled for the first of the above two defence payloads. Atlantis is employed for the HST on account of its higher performance enabling the telescope to be raised to a higher orbit with a longer orbital life-time.

Once in orbit the telescope will be lifted from the orbiter's payload bay at the end of the arm of the Canadian-built Remote Manipulating System enabling the solar arrays to be unfolded and power provided for the checkout of the main systems. Should a solar array fail to unfold an astronaut in EVA will have the job of hand-cranking it open. Should the telescope, be inoperative for any reason the option will still be available to replace it in the payload bay and return with it to Earth. If functioning satisfactorily, the Shuttle will fly in formation with it, some 40 miles away, for the remainder of the mission while checkouts continue. The

Optical performance of HST.



facility will still be available to return the HST to Earth with the Shuttle if checkouts do not go as planned. Full operational status will not be reached until after several months of testing during which time some of the first spectacular images should be obtained.



The HST at the Lockheed Sunnyvale facility undergoes functional testing including an acoustic test which simulates the vibrations encountered during launch. Lockheed is responsible for systems integration and engineering.

HST Organisations and Management

The Office of Space Science and Application at NASA Headquarters is responsible for overall programme management, financial and scheduling provisions, and the science policy development and direction.

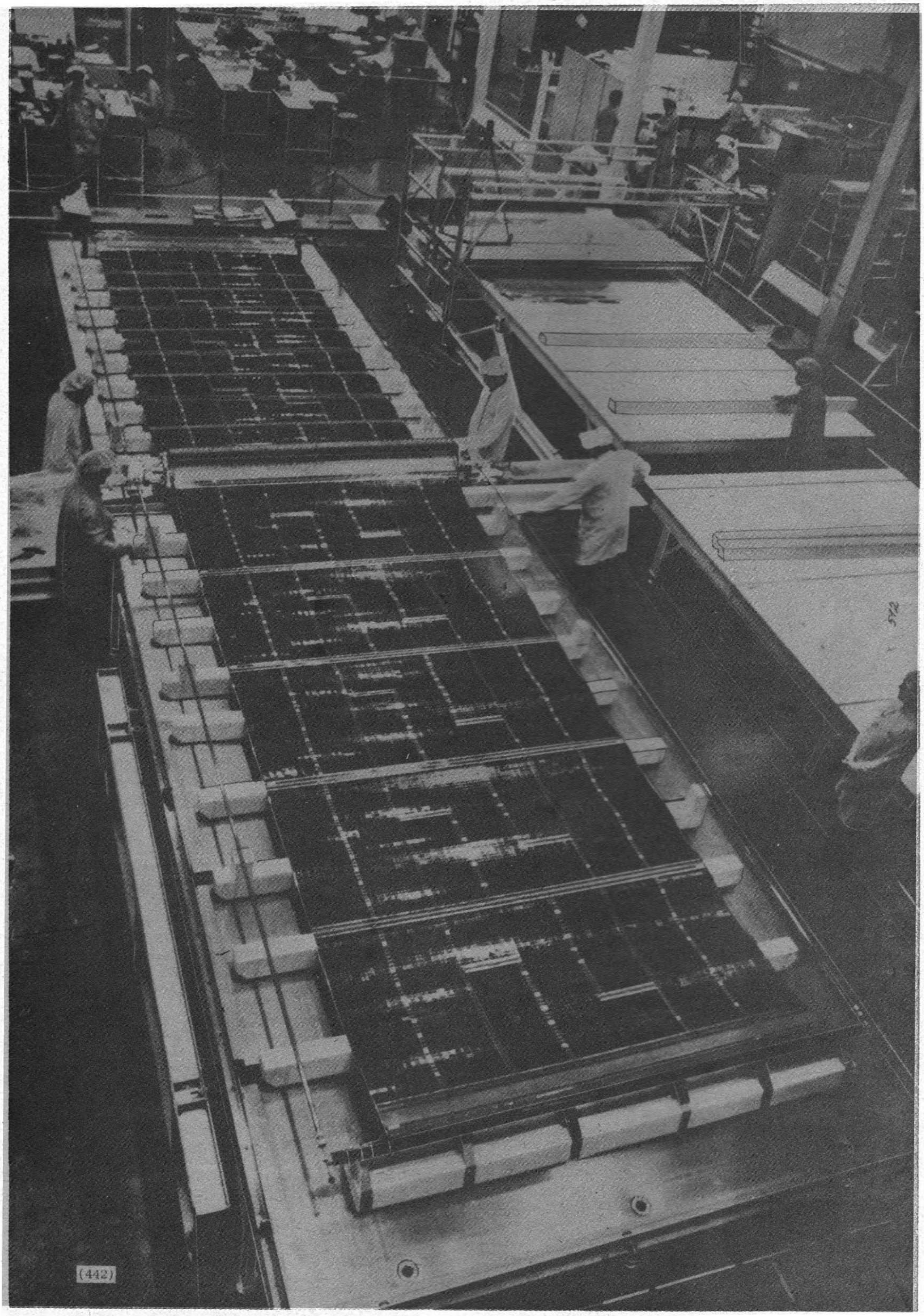
Marshall Space Flight Center in Huntsville, Alabama is responsible for the development and operation of the Space Telescope system as the "lead" NASA Centre.

In Greenbelt, Maryland, the Goddard Space Flight Center is managing the scientific instruments, mission operations, and data management. It is also charged with monitoring the Space Telescope Science Institute, which is located on the Homewood Campus of Johns Hopkins University in Baltimore, Maryland. The Institute determines the observational programme of the Space Telescope while on orbit, insuring that the observatory will be used to its maximum advantage. It is operated by AURA, the Association of Universities for Research in Astronomy.

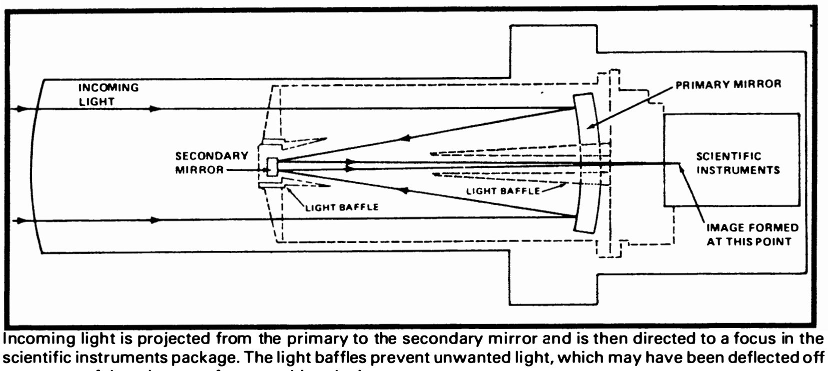
Lockheed Missiles & Space Company, Sunnyvale, California, is the systems integrator of the Space Telescope satellite and is also responsible for the design, development and manufacture of the Support Systems Module.

Perkin-Elmer Corporation, Danbury, Connecticut, manufactured the Optical Telescope Assembly. Other contractors involved with primary components are:

Faint Object Spectrograph	*Martin Marietta*
Faint Object Camera	*European Space Agency (Dornier/Matra/British Aerospace)*
High Resolution Spectrograph	*Ball Brothers*
Wide Field/Planetary Camera	*NASA Jet Propulsion Laboratory*
High Speed Photometer	*University of Wisconsin*
Solar Arrays	*European Space Agency (British Aerospace)*
Science Instrument Control and Data Handling	*Fairchild/IBM/Goddard Space Flight Center.*



(442)



Incoming light is projected from the primary to the secondary mirror and is then directed to a focus in the scientific instruments package. The light baffles prevent unwanted light, which may have been deflected off some part of the telescope, from reaching the instruments.

HST Promises New Results

The Hubble Space Telescope carries five scientific packages. Four of them, about the size of telephone booths, are located in the aft shroud, behind the primary mirror and receive light directly from the secondary mirror. The fifth one, a Wide Field/Planetary Camera, is located on the circumference of the telescope and uses a pick-off mirror system. The five experiments are:

Faint Object Camera (FOC)

The FOC does exactly what its name implies, observes faint objects. It does this by taking very low light levels and electronically intensifying the images. Objects as faint as 28th or 29th magnitude (the higher the magnitude, the fainter the object) should be observed the FOC. By comparison, Earth-based telescopes can see to about 24th magnitude.

Likely targets for the instrument are the search for extra-solar planets, variable brightness stars, and in its spectrographic mode, the centre of galaxies suspected of concealing black holes.

Faint Object Spectrograph (FOS)

The FOS will measure the chemical composition of very faint objects. Visible light contains information used to determine the chemical elements which make up the light source. Special gratings and filters allow the FOS to make spectral exposures which not only reveal information about the makeup of a light source but also about its temperature, motion and physical characteristics.

This instrument will study the spectra of objects in the ultraviolet and visible wavelengths. Particular targets of interest are quasars, comets and galaxies.

High Resolution Spectrograph (HRS)

While performing in much the same way as the FOS, this instrument will observe only the ultraviolet portion of the spectrum. It will be used to investigate the physical make-up of exploding galaxies, interstellar gas clouds, and matter escaping from stars. The instrument is described in more detail below.

High Speed Photometer (HSP)

With no moving parts, the HSP is the simplest of the five instruments. It will measure very exact the intensity of light coming from stellar objects. In addition, it will provide very precise measurements, down to the microsecond level, of time variations in the light.

The amount of light received from an object is an important factor in determining its distance, making the HSP useful in refining the scale of the Milky Way galaxy and other nearby galaxies.

Wide Field/Planetary Camera (WF/PC)

Actually two separate cameras in one housing, the WF/PC should return some of the most spectacular visual images from the HST. In the Wide Field mode the instrument will view large areas of space and provide exquisite views of galaxies and star fields. In the Planetary mode, it will provide glimpses of the planets comparable to those obtained on close fly-by missions.

In-Orbit Servicing

An extraordinary feature of the HST is its design for in-orbit servicing. Later Shuttle launchings will be undertaken to enable EVA astronauts to go onboard the telescope and refurbish or repair equipment or replace some of the major items such as the solar arrays or any of the five scientific packages.

A second generation of scientific instrumentation is proposed for installation in 1992 to 1994 and design work is already in hand, although firm decisions will not be taken until after the first year of telescope operation and future scientific needs have been assessed.

The present solar arrays are expected to gradually lose power due to chemical erosion by atomic oxygen

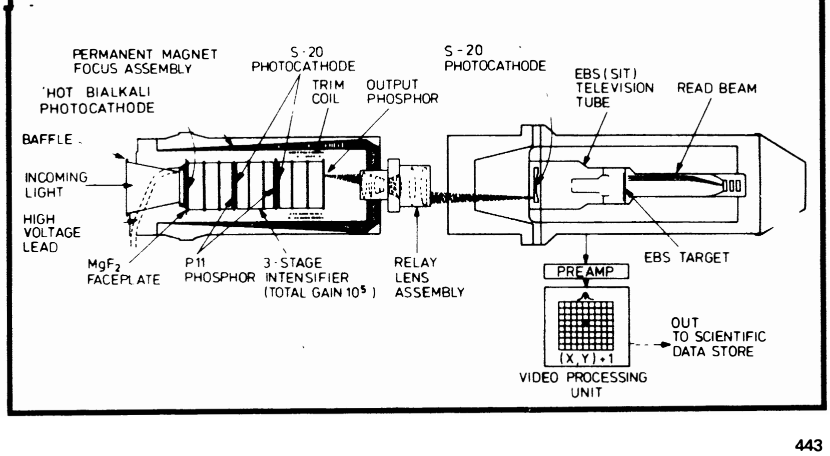
ESA Contribution

Observing time on the telescope will go to scientists from member nations of the European Space Agency in recognition of ESA's contribution to the project.

ESA has an agreement with NASA arising from its first involvement in 1975 and approval by the ESA Council in 1976 for a 15 per cent participation. ESA has undertaken to support the telescope for 10 years in respect of the solar arrays and all associated mechanisms and electronics for deployment and slewing and also with the Faint Object Camera.

The solar arrays have been built by a consortium led by British Aerospace Space and Communications Division, Bristol, England and are among the largest ever built with two solar panels unrolling from a single drum on either side of the telescope. Their total area is 365 square feet containing over 48,000 solar cells with a total power output of 4.6 kW and an expected orbital life of five years.

British Aerospace has been involved also in the Faint Object Camera as leader of the consortium manufacturing the Photon Detector Assembly. In this device image photons are individually counted by what consists of an intensifier tube coupled by a relay lens assembly to a camera tube which detects the scintillations at the intensifier output. The arrangement is shown in the accompanying diagram.



The Space Telescope Solar Array at BAe Bristol during the final testing of the wing prior to shipment to the US on May 5, 1986. The wing has just been fully deployed on the water table. The array cannot support itself deployed under 1 g and it must be supported on polystyrene floats on water.

which is the main atmospheric gas at HST orbiting heights. The second-generation solar arrays will be designed against atomic oxygen degradation and contracts are due to be placed for this work to begin in 1987.

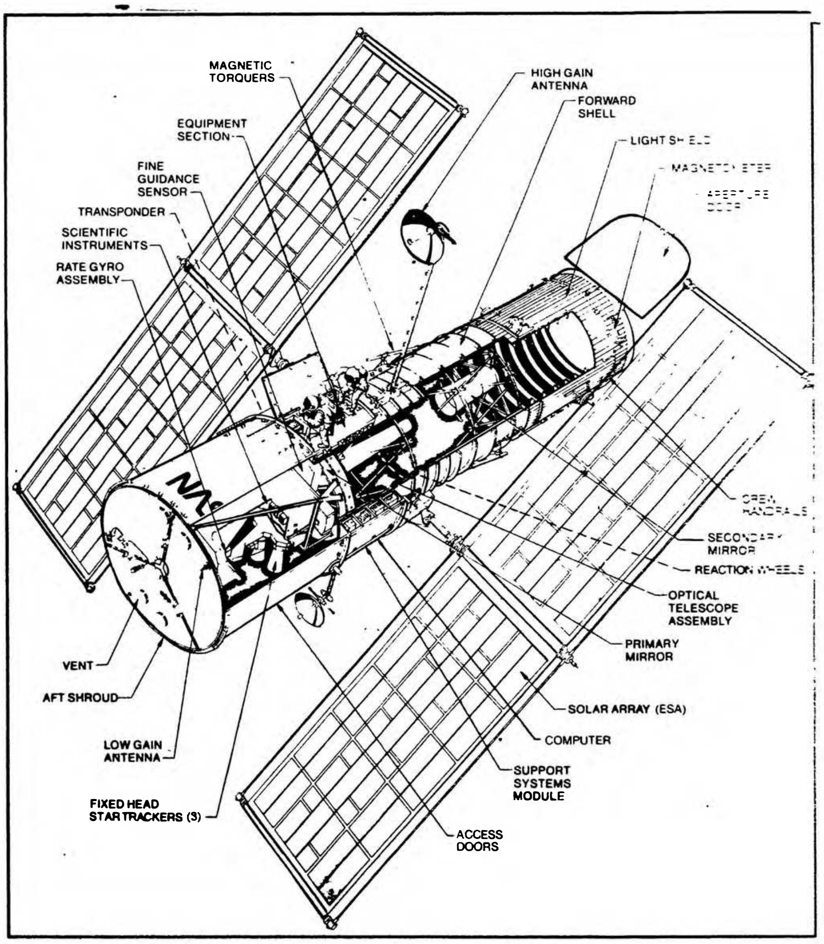
With the arrival of the solar cycle maximum around 1990 to 1991 air drag effects on the HST will maximise and by the early 1990's the orbit may drop to its lowest acceptable height of 305 nautical miles. A re-boost would then be required either by a visiting Shuttle orbiter or, if available, by the planned Orbital Maneuvering Vehicle which would be capable of raising the HST to 380 nautical miles height from where orbital needs would be satisfied for the duration of the project's expected life.

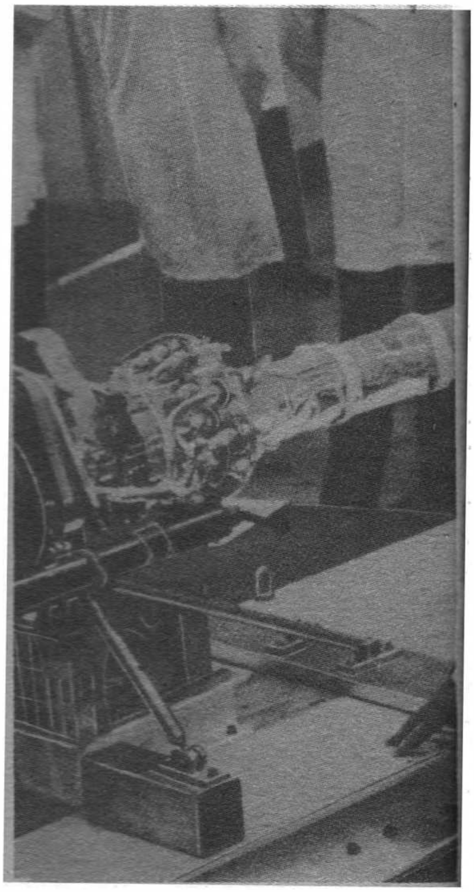
Current Status

The HST was due to leave the Lockheed Missiles & Space Company at its Sunnyvale, California facility after completion of systems integration and engineering in August 1986 and travel by ship through the Panama Canal to be installed at the Kennedy Space Center in the payload bay of the Atlantis orbiter.

In the present circumstances, the telescope has remained at Lockheed's Sunnyvale facility, where during the summer it successfully underwent two months of rigorous testing much of which involved conditions of temperature and pressure similar to those to be experienced in space and included linking it to the Space Telescope Operations Control Center at NASA Goddard to provide what is called an end-to-end test. Also involved in these tests were members of the European Space Agency which has supplied the telescope's large solar arrays and one of the scientific packages, the Faint Object Camera.

The solar arrays, which were delivered to Lockheed in May 1986, were due to be fitted during the first week of November not having been required for the ground testing recently completed. Four of the five scientific packages have since been removed, three for telemetry servicing and one for a change of baffles. The number of personnel working of the HST project is currently being run down, having been halved in the last six months, and now stands around 1500 including personnel at the various contractors. A summary of the main HST organisations appears on page 441.





HST Design Features

Optical Telescope Assembly (OTA)

The heart of the Space Telescope is the Optical Telescope Assembly. The major segments of the OTA are the 94.5 inch (2.4 meter) primary mirror, a secondary mirror of 12 inch (0.3 meters) and the OTA's support structure.

The precision of the primary and secondary mirrors is a major ingredient in the superb capability of the Space Telescope. If the mirrors were scaled up to the size of the Earth, none of the great mountain ranges would tower more than 5 inches above the lowest point.

Light entering the Space Telescope is reflected off the primary mirror to the secondary mirror, 16 feet (4.5 meters) away. The secondary mirror sends the light through a hole in the centre of the large mirror, back to the scientific instruments as shown in the diagram on page 443.

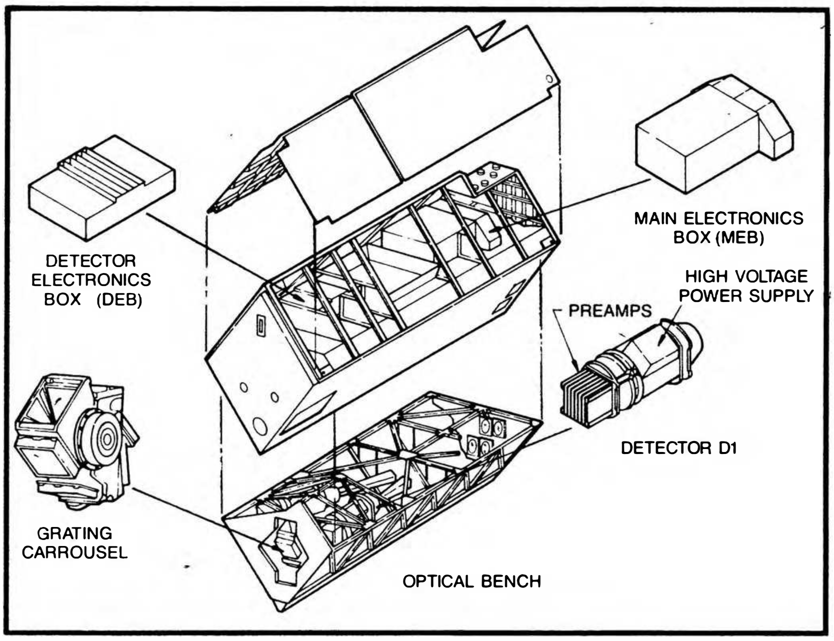
Support Systems Module (SSM)

The SSM directs communications and commands the power thermal and attitude control systems, the latter providing the fine pointing control for the telescope.

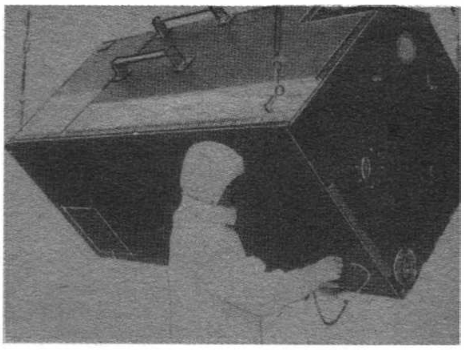
Collectively, the SSM consists of the main structure of the spacecraft consisting of the light shield on the front end of the telescope; the equipment section with the main spacecraft electronics equipment; and the aft shroud, which contains the scientific instruments. More details are shown in the diagram above.

Fine Guidance Sensors (FGS)

The Fine Guidance Sensors feed roll, pitch and yaw information to the telescope's attitude control system. To point the telescope, the FGS must first identify the position of specified stars. It will then allow the telescope to point with a stability of 0.007 arc seconds, or roughly the equivalent of focusing on a dime in Los Angeles from a vantage point in San Francisco.



A cutaway drawing of the High Resolution Spectrograph.

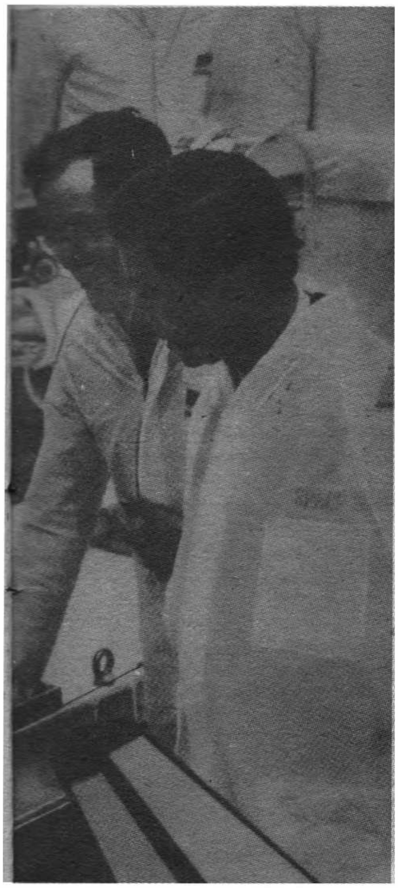


The High Resolution Spectrograph.

The High Resolution Spectrograph

by Richard Greenwall and Maureen Hogg

Prince Charles inspects the Solar Array for the HST during a visit to the BAe Bristol site, UK Installation of the arrays on the Space Telescope at Lockhead was due to start in early November.



Space astronomers can look forward to improved spectroscopy for narrow band and faint continuum emission in the ultraviolet spectral range when the High Resolution Spectrograph (HRS) is launched aboard the Hubble Space Telescope (HST) in 1988.

The HRS mission will be to collect data in the ultraviolet wavelength range from 105 to 320 nanometers with three selectable spectral resolutions and two selectable spatial resolutions.

Dr. John C. Brandt of NASA Goddard Space Flight Center and 15 scientific investigators from the United States and Canada now plan to study the interstellar medium, stellar winds and extragalactic sources such as quasars and the Seyfert galaxies. Studies of the atmosphere of Jupiter and its moons may also be made.

Built by the Aerospace Systems Division of the Ball Corporation, Boulder, Colorado, the HRS is one of five scientific instruments located at the focal plane of the 2.4 meter (94.6 inch) HST. Ball Corporation has applied the latest technologies in mechanical design, as well as optical and electronic design, to achieve the high accuracy and high stability demanded by observation sequences lasting from minutes to hours.

In this article, which has been specially prepared for *Spaceflight, Richard Greenwall* and *Maureen Hogg* present an overview of the state-of-the-art design features of the HRS.

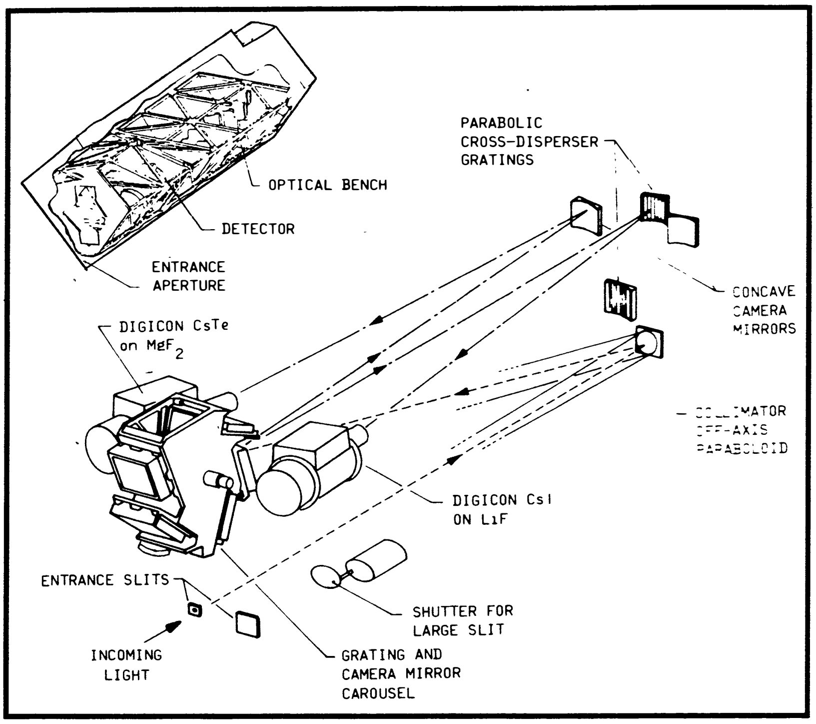
Mechanical Design

A drawing of the HRS instrument is shown above. The structural enclosure is constructed of 6061-T6 aluminium and contains a graphite-reinforced epoxy optical bench and a separate compartment for the instrument electronics boxes. A ball-and-link, quasi-kinematic support structure mounts the enclosure to the HST structure. The instrument measures 218 x 90 x 90 centimeters (86 x 36 x 36 inches) and weighs 310 kilograms (700 pounds).

Within the enclosure, a thermal barrier runs diagonally across the length to form two compartments. The upper compartment contains the electronics boxes. The lower compartment contains the optical bench which combines plates and tubular trusses to achieve a maximum dimensional change in the length of the optical bench of 70 x 10^{-6} inches and a thermal coefficient of expansion of 0.114 x 10^{-6} in/in/°C. All optical elements are made from low thermal expansion substrates for thermal stability. The calibration sources, drive mechanisms and detector photocathodes are mounted on thermal standoffs to minimise thermal conduction to the optical bench. The photocathodes are cooled to less than 20°C by radiative coupling to a cooler on the enclosure's external surface. Active resistive heaters with proportional temperature control are mounted to the thermal barrier to generate a controlled environment of 21 ± 4°C. In designing the instrument a thermal model with 206 nodes was used to ensure optimal thermal and structural performance.

Optical Design

The HST will collect light in the ultraviolet wavelength region and will focus 70 per cent of the light within a circular radius of approximately 0.1 arc second. The HRS capitalises on this high image quality by using two selectable spectrograph entrance apertures. The larger aperture is 0.559 x 0.559 mm (2 x 2 arc seconds) and is primarily used to acquire the targets. The smaller aperture is 67 x 67 micrometers (0.25 x 0.25 arc second). The second,



The optical system of the High Resolution Spectrograph.

smaller aperture isolates the target from scattered light and nearby objects, precisely images the scene on the detectors and achieves a better image profile on the detector.

The spectrograph itself is a modified Czerny-Turner design. Six gratings and an acquisition mirror are mounted on a rotatable carrousel to image spectra on two detectors, effectively performing the functions of seven spectrographs in a single instrument. Five of the gratings are plane gratings of medium and low resolution; grating six is an echelle grating with two sub-modes and high resolution. Table 1 gives a breakdown of wavelength coverage and spectral resolution for the gratings.

The carrousel is driven by a brushless motor and an optical encoder provides position readout. The encoder operates in a commandable, digital mode with a 16-bit resolution and an angular rotation per bit of 19.78 arc seconds. The carrousel is capable of a 180° slew in less than 20 seconds. The carrousel position is repeatable to ±0.3 arc seconds and stable to within ±0.03 arc second.

Table 1: HRS Spectral Characteristics

Grating	*Spectral Range (nm)*	*Spectral Resolution*
1	105–170	2×10^4
2	110–210	2×10^4
3	160–230	2×10^4
4	220–320	2×10^4
5	105–170	1×10^3
6		
Sub-mode A	110–170	1×10^5
Sub-mode B	170–320	1×10^5

Light dispersed by any of the five plane gratings is passed to camera mirrors for imaging on the appropriate detector. Light from the echelle grating is passed to one of two cross-disperser gratings. All optical surfaces have special coatings to optimise their response in the given spectral ranges. Two calibration lamps provide flat-field illumination and two lamps provide spectral lines for in-flight calibration.

Detectors

Two Digicon detectors are used with permanent magnetic focusing assemblies (PMFA) and deflection coils to focus and deflect photoelectrons accelerated to 25 keV onto a 512-element linear diode array. Detector 1 (D1) has a cesium iodide photocathode deposited on a lithium fluoride window and is used in the 105-170 nanometer wavelength range. Its quantum efficiency has a peak of 15 percent at roughly 130 nanometers. Detector 2 (D2) uses a cesium telluride photocathode deposited on a magnesium fluoride window and covers the 115-320 nanometer wavelength range.

The deflection system has a 12-bit resolution and incremental steps of 6.25 nanometers in the vertical and horizontal with a full-scale vertical range of ±12.8 millimeters. Each detector uses individual signal processing electronics that include hybrid preamplifiers and postamplifiers.

A key element of the detector performance is that extreme sensitivity should remain constant for long integration times of weak light without detector noise swamping the signal. Ball Corporation used a special ultraviolet vacuum test facility to evaluate these parameters. A detector and its high voltage power supply were installed in the test chamber and the atmospheric pressure was reduced to 10^{-6} torr. The detector was operated for up to 1,000 hours while being monitored for dark count rate. The dark counts were 0.0009 counts/second/diode or less, compared with the requirement of 0.01 counts/second/diode. When the detectors were placed in the HRS, calibration tests showed a dark count rate equivalent to 4 counts/diode/orbit in flight, with an orbital period of 90 minutes on average. The low noise coefficient also contributes to a greater dynamic range; dynamic range being determined by dark count at the lower end and by saturation of the pulse-counting electronics at the high end. Each detector can count from 0.001 to over 150,000 counts/channel/second for a dynamic range of greater than 10^8.

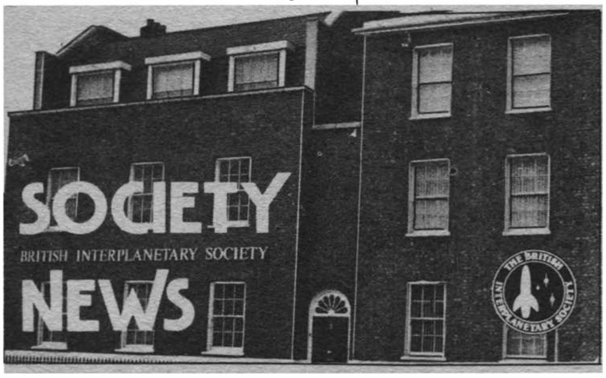
Detector Electronics

The detector signal processing electronics uses large-area hybrid preamplifiers and postamplifiers to achieve high input impedance of 10^8 ohms, low noise, and minimal cross talk, in addition to small volume and low weight. A total of 128 hybrids is used for 1,024 channels: each detector has 32 preamplifiers with 16 channels per preamplifier, which are packaged in nonmagnetic, hermetic cases and mounted directly to the detector backplate. The postamplifiers are also allotted 32 to a detector, 16 channels to a postamplifier, and are packaged in nonmagnetic, hermetic cases connected by special cabling to the preamplifiers and located in a separate detector electronics box. The preamplifier hybrid measures 5.5 x 3.2 x 0.185 inches and weighs 95 grams. The postamplifier hybrid measures 12.1 x 3.6 x 0.185 inches and weighs 215 grams.

The threshold circuitry for each diode can be individually set and is typically set at 50 per cent of the energy corresponding to the peak. This setting reduces noise counts without significantly reducing the probability of detecting a photon-induced pulse. Each channel has independent logic to transfer data to a redundant signal processing unit. If failure occurs, the HST is programmed to cover the defective area by deflecting the signal to adjacent channels. Data are taken as pulse rate, processed as digital signals, and flagged for noise. Data are returned at a rate of 1 mega bit per second and the maximum on-orbit power consumption is 150 watts.

Acknowledgements

The authors wish to thank those technical specialists and managers at NASA Goddard Space Flight Center and Ball Aerospace who supported the compilation of this article.



SPACE '86 FOLLOW-UP

The Society has received with pleasure many compliments concerning the arrangements and programme of its SPACE '86 meeting at the Brighton Centre at the end of September. In turn, we express our gratitude to those who participated as speakers or who helped in many different ways to ensure an outstandingly successful event.

Cameras were put to good use during the SPACE '86 meeting by many participants including Douglas Arnold and Joe Kneba who both generously gave of their services to provide an 'official' photographic record. We gratefully acknowledge their excellent coverage which is well illustrated by the photographs that appeared in the November issue of ***Spaceflight***.

Participants have written to us as follows:

A big thank you and congratulations to all who put so much effort in arranging Space '86. The fact that the weekend ran almost like clockwork was evidence enough of the work that must have gone into it.

I was also very pleased to be present at the presentation of the NASA Award to Len Carter. Congratulations!

M.A. COWELL, Surrey

This is just to say that I enjoyed the conference very much and to congratulate the BIS staff on maintaining the high standard set with the two previous events. In the face of strong competition (Laeser, Arnold, Parkinson, the astronauts ...) the highlight for me was Dr. Bekey's paper – magnificent!

G. RICHARDS, Surrey

The Society's weekends-by-the-sea, held at Brighton Centre in 1982, 1984 and again this year, have provided a unique venue for the presentation of results, plans and ideas. The 1986 conference, as in previous years, succeeded in bringing together speakers on a wide variety of topics.

Richard Laeser and I switched the order of our presentations so that he could go to London in time to attend the wedding of William Herschel's great-great-great-great-granddaughter. Herschel, the discoverer of Uranus in 1781 and the infrared region of the spectrum in 1800, has functioned almost as a patron saint for JPL in the mid-1980s since these two discoveries provided the basis for not only the Voyager encounter with Uranus but also for the mission of the Infrared Astronomical Satellite (IRAS) in 1983.

The banquet on Saturday evening at Space '86 offered a chance to relax and to pursue some topics in greater detail. After dinner and the Loyal Toast, "to the Queen", the speakers including Roy Gibson, who heads the British National Space Centre, were sparkling. But the highlight for me was the brief ceremony when Society Fellow Robert Freitag, from NASA Headquarters, presented the Public Service Medal to Len Carter, Executive Secretary of the BIS: well deserved and well done.

W.I. McLAUGHLIN, JPL

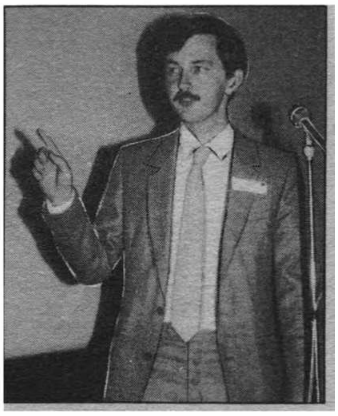
COUNCIL ELECTIONS

Following the recent elections to Council at the 41st AGM, Dr. J.K. Davies joins the Council for the first time and Professor I.E. Smith returns after several years. Mr. A.T. Lawton and Mr. C.R. Turner were re-elected.

Dr. J.K. Davies is an astronomer and aerospace engineer. After gaining his PhD in physical chemistry from the University of Nottingham in 1976, he became a flight test engineer at British Aerospace's Warton Airfield for three years. Whilst working at British Aerospace he continued to expand his scientific background by researching, on a part time basis, with Dr D.C.B. Whittet (Preston Polytechnic) on a composition of interstellar and circumstellar dust.

In 1982 John joined the Department of Astronomy at Leicester University to carry out a search for moving object using data from the Infrared Astronomical Satellite (IRAS). This resulted in his discovery of six new comets, including comet IRAS-Araki-Alcock which missed the Earth by only three million miles in May 1983. He also discovered a huge, and hitherto unknown dust tail on the periodic comet Tempel-2 besides several asteroids. At the conclusion of the IRAS mission John took part in the first stages of the UK preparations for the return of Halley's Comet before moving to the Space Research Department at the University of Birmingham. At Birmingham he is involved in the development of an ultraviolet space telescope which will be launched as part of the ROSAT X-Ray and extreme UV sky survey mission.

John writes and lectures on space and astronomy topics. His articles have appeared in ***Spaceflight*** among many other magazines. He has given many informal lectures to amateur astronomy groups, contributed to TV and Radio programmes such as "The Sky at Night" and "Science Now", and recently published a book "Cosmic Impact".



Dr. J.K. Davies.

Professor I.E. Smith was educated at Bootham School, York and at Lancaster Royal Grammar School and entered Manchester University to study Chemistry. After graduating in 1947 he continued with a one-year conversion course in Chemical Engineering and in 1950 received an MSc in that subject. Two years' service with the Distillers Company led to an interest in combustion phenomena and in 1953 he was appointed Research Assistant at Imperial College under the

Prof. I.E. Smith.

late Professor Sir Alfred Egerton. Following his PhD in 1955 he was awarded an AGARD Fellowship at Princeton University and for the next two years worked under Professor Crocco in the field of Liquid Rocket Combustion.

In 1958 he joined Rolls Royce with Val Cleaver and Stephen Bragg in the Blue Streak Propulsion Team and in 1960 became Chief Performance Engineer. Following the successful launch of F1 he transferred to the Air Breathing Combustion research side of Rolls Royce (Derby), and after a year in that post was appointed Senior Lecturer at the then College of Aeronautics, Cranfield. For nearly eight years he Chaired the ARC Rocket Propulsion Sub-committee until the demise of the ARC during which time he continued research in the field of Liquid Propellant Engines as well as the Ignition of Solid Propellant Rockets.

Since 1975 his activities have been mainly in the field of Energy and Energy Conservation and in 1978 was appointed to a personal Chair at the Cranfield Institute of Technology. Happily (for him) he now has the opportunity to indulge in studies on the Hotol propulsion system with some of his former colleagues at Rolls Royce, and, of course, Alan Bond whose genius inspired the engine system. He still retains connections with the present tenants of Spadeadam, the Blue Streak test site, and recently arranged for the transfer of a goodly selection of RZ2 rocket components to the Museum which is being established there.

REPORT OF 41st AGM

The 41st AGM was held in the Society's Conference Room on 20 September 1986 with the President in the chair, four other Members of Council, the Executive Secretary and 12 Fellows and Corporate Members present.

The President read out the main highlights of the Report of the Council on the Society's affairs for the year ending 31 December 1985, which had already been distributed to members by publication in ***Spaceflight***.

Introducing the Accounts, the Executive Secretary pointed out that the most significant fact was that a small deficit had occurred during the year. This would always be inevitable unless income increased, either by higher membership or higher subscriptions, to keep pace with the Society's own expenses. On the proposal of the President, the accounts were approved unanimously. It was agreed that the present Auditors continue in office and that their remunerations be fixed by the Council.

Nominations for election to Council had been received from Dr. J.K. Davies, A.T. Lawton, Professor I.E. Smith and C.R. Turner. The President stated that, as there were four nominations for four vacancies, the matter could be resolved by the meeting. He therefore proposed that all four be elected. This was agreed unanimously.

The meeting concluded with a general discussion. A

SOCIETY MEETINGS DIARY

All meetings unless otherwise stated are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ.

28 January 1987, 7-9 p.m. **Film Show**

THE BORDERS OF SPACE (Part 1)

Two film shows will highlight important stages in the development of manned space exploration.

The programme will include the following:

(a) The Legacy of Gemini.
(b) Apollo 15: To the Mountains of the Moon.
(c) Four Rooms, Earth View (Skylab).
(d) STS-2: Post-Flight Press Conference.
(e) STS-5: Post-Flight Press Conference.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

25 February 1987, 7-9 p.m. **Film Show**

THE BORDERS OF SPACE (Part 2)

The second of two film shows continues the survey of important manned space missions.

The programme will include the following:

(a) The Four Days of Gemini 4.
(b) The Mission of Apollo-Soyuz 15.
(c) STS-6 Post-Flight Press Conference.
(d) STS-8 Post-Flight Press Conference.
(e) The Space Station

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

11 March 1987, 7-9 p.m. **Lecture**

WHEN IS SPACE NEWS?

by F. Miles

Once, in the days of Apollo, there was tremendous television and press interest in space. Now it seems to take something like the Challenger disaster to arouse media interest. What *are* the constraints on reporting space news? How *do* editors decide what is worth reporting? Frank Miles has been handling space stories on ITN since the 1960 — and might have some answers.

LIBRARY

The Society Library will be open to members from 5.30 p.m. to 7 p.m. on the following dates:

28 January 1987
25 February 1987
11 March 1987

member expressed satisfaction that ***Spaceflight*** was, at last, now appearing on the bookstalls. Another member expressed pleasure that the Society would be hosting the 1987 IAF Congress. The Executive Secretary replied that arrangements were very well advanced for what was a most complex task. Even though the Society had organised two earlier Congresses, the requirement for facilities was now substantially greater. The President thanked those present for their contributions to the discussion and declared the meeting closed.

TRANSFER TO FELLOW

Under the Society's new Constitution and revised Bye-Laws, many Corporate Members (i.e. members whose date of election is earlier than 31 December 1985) now become eligible for transfer to Fellow. On payment of their renewal subscription for 1987, Corporate Members will automatically be considered for transfer to Fellow and notified in due course. No individual application is required as the subscription rates for the two grades are now the same.

Any Non-Corporate Member may apply at any time for transfer to Fellow on the basis of contributed work. Details are available on request.

Fellows are entitled to use the designation F.B.I.S.

37th IAF CONGRESS

The Society was formally represented at the Congress of the International Astronautical Federation (IAF) at Innsbruck, 4-11 October 1986, by Dr. L. R. Shepherd, a Vice-President of the Society and L.J. Carter, Executive Secretary.

The IAF now consists of 79 member organisations and the 1305 attendees at the Congress came from more than 30 counties. About 500 technical papers were presented in 61 sessions.

The host country, Austria, was founder member of the Federation in September 1950 and provided excellent lecture rooms and technical facilities for this year's 37th annual Congress held in the Kongresshaus Innsbruck. The meeting was further enhanced by a Space Technology Exhibition in the Dogana Hall of the Kongresshaus where space hardware from all parts of the world was on show.

Dr. Johannes Ornter of Austria was nominated as President of the Federation for the next two years. At the Congress Banquet, Dr. Ortner made an informal gesture of goodwill to the BIS, as organisers of next year's Congress at Brighton, U.K., with the presentation of an Austrian cow-bell, which was received on behalf of the Society by the Assistant Executive Secretary, Shirley Jones.

Ice With Your Evolution

A. Berry, Harrap Books, 1923 Ludgate Hill, London EC4 7PD. 1986, 192pp, Hardback, £9.95.

The author, described as 'a Science Writer with a difference' by Patrick Moore, lives up to his reputation in eleven short essays in this book which cover a wide range of scientific issues such as war and peace, the environment, astronomy and space travel.

Chariots of Apollo: The Making of the Lunar Module

Eds. C.R. Pellegrino & J. Stoff, Atheneum Publishers, 115 Fifth Avenue, New York, N.Y. 10003 USA. 1986, $17.95

At no time in history has the World's imagination been captured so much as when men first walked on the Moon. Those first, hesitant steps were the fruits of efforts by designers and technicians over a long period to conceive the necessary craft, carry it through and struggle to final success.

This book unfolds the fascinating story in behind-the-scenes and in-depth looks at many of the people and events that made this unique event possible.

Starting with the first Soviet spacecraft and President Kennedy's decision to enter the space race, using first-person accounts, correspondence and dialogue re-created to the best recollection of the poeple involved the authors, Fellows of the British Interplanetary Society, describe the camarderie and uncertainty, exhilaration and frustrations of those who devoted six years of their lives to this historic project,

The Physics of Atmospheres

J.T. Houghton. Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU. 1986. 271pp. £9.95 (paperback).

Several factors have led to a vigorous growth in the study of atmospheric sciences in recent years. One is the availability now of powerful computers able to undertake detailed modelling; another is the investigation of the atmospheres of other worlds by space probes and a third is the area of improved techniques in remote sensing generally. All these have made necessary a second and revised edition of a most useful textbook.

The study of the Earth's global atmosphere is currently being emphasised by the existence of a large international programme, the Global Atmosphere Research Programme to study some of the basic problems which at present prevent a proper understanding of the behaviour and circulation of the Earth's atmosphere as a whole, as well as the mechanisms which determine climatic change.

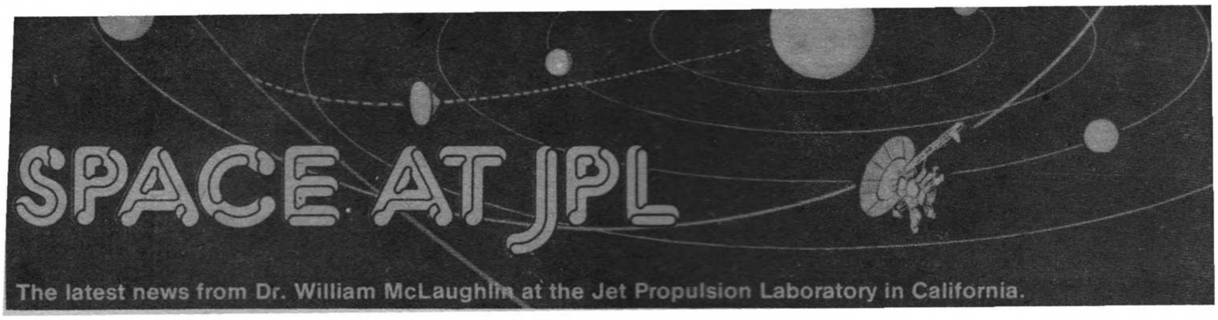
The book is eminently suited for undergraduates or graduate students studying atmospheric physics, climatology or meteorology. It will also be of value to many planetary scientists with an interest in atmospheres.

Manned Spaceflight Log

T. Furniss. Jane's Publishing Co. Ltd., 238 City Road, London EC1V 2PU. 1986. 160pp. £7.95.

The popularity of this work is shown by the fact that a new edition has appeared after only three years, offering a digest of manned space flights from Yuri Gagarin on April 12, 1961 to the flight of Soyuz T15 on March 13, 1986, a total of 128 flights thus being logged. Each is accompanied by descriptive text of the launch and the results achieved, coupled with photographs of the astronauts/cosmonauts involved or of their launch vehicles or capsules.

This edition also includes the 13 missions by the X-15 Rocket aircraft, all of which exceeded an altitude of 50 miles between 1962 and 1968 and thus, effectively, flew into Space.



In this issue Dr. McLaughlin presents three reports arising from his recent visit to Europe.

Space Missions to Halley's Comet

Although the analysis of scientific data obtained during the recent apparition of Halley's comet will continue for years to come – Ray Newburn, of the International Halley Watch, estimates that over 20 gigabytes (a number equal to "2" followed by 10 zeroes) were collected by ground-based observers alone – some perspective can now be gained with respect to the whole endeavour.

Professor Reimar Lüst, Director General of the European Space Agency, gave the first International Academy of Astronautics scientific lecture on the topic: "Space Missions to Halley's Comet," in a joint meeting with the Austrian Academy of Sciences in Vienna on October 3. He reviewed the history of the development of our knowledge about comets, the physics and astronomy of these "hairy stars" ("coma" means "hair" in Latin), the constitution of the Halley armada of spacecraft, the missions of discovery, and some of the scientific results.

One of the first scientific results concerning comets was obtained by the master of observational astronomy, the Dane, Tycho Brahe. In 1577 he demonstrated by measuring the parallax of a comet that it was beyond the orbit of the Moon and certainly not an atmospheric phenomenon as some astronomers had thought. With his universal mechanics, Newton furnished the means by which Edmond Halley was able to compute cometary orbits and, indeed, predict the return in 1759 of the comet now known by his name, an event which occurred 17 years after his death.

In more recent times, the source of comets was hypothesised by the Dutch astronomer Jan Oort (1950) to be a vast cold icebox tens of thousands of astronomical units beyond the Sun. This "Oort Cloud," as it has come to be called, may contain over 10^{12} comets and, when perturbed by stellar gravity fields, can send individual comets into the inner solar system. Some are captured by the gravity of Jupiter or the other gas giants; others pass back to their source on long, highly elliptical paths.

When comets are beyond about the orbit of Jupiter, they consist simply of a nucleus several kilometres in diameter, a conglomerate of ice, dust, and rock – "a dirty snowball" – according to the American cometary astronomer Fred Whipple. Emission of gas and dust begins as the comet approaches the Sun, forming a coma about the nucleus and one or more tails.

The Halley armada consisted of the ESA spacecraft Giotto, two Soviet Vega spacecraft, and the two Japanese spacecraft Suisei and Sakigake. In addition, the American ICE spacecraft, which had flown through Comet Giacobini-Zinner in September of 1985, made a very distant encounter with Halley's comet. The encounters were bunched in March of 1986 because on March 10 Comet Halley passed through the plane of the Earth's orbit (ecliptic), at which time the energy requirements were moderate for Earthly visitors. Comet Halley is inclined at a very large angle to the ecliptic, which makes it travel around the Sun in a direction nearly opposite to the Earth and to spacecraft arriving from Earth. In a jocular reference to English motoring rules, Lüst said that this was entirely appropriate for an English comet. The practical effect of retrograde motion is, of course, that encounter speeds were quite rapid for the spacecraft; Giotto flew by at 68.4 km/s.

The reasons for choosing Comet Halley for an object of reconnaissance were several. Its orbit was reasonably well known, the energy requirements to reach it were moderate, it has had a high rate of production of dust and gas (making it of increased scientific interest), and it has been of considerable historical interest through the centuries.

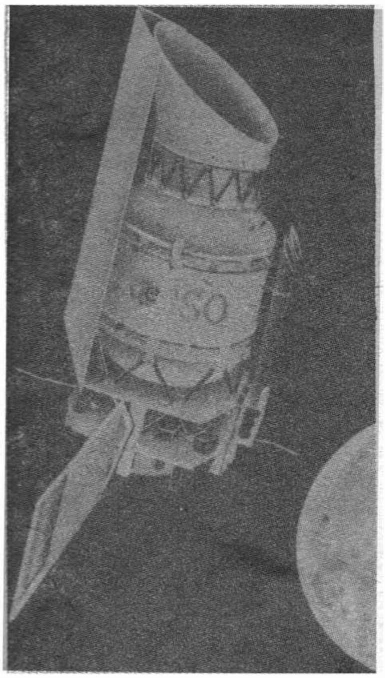
• Professor Reimar Lust.

The Giotto spacecraft was launched by an Ariane vehicle on July 2, 1985 for its planned March 13, 1986 encounter with the comet. The spin-stabilised spacecraft (one rotation every four seconds) had a mass of 574 kg on the encounter date and was provided with shields to protect against the expected onslaught of cometary dust.

Prior to the encounter, in late January, just as Voyager 2 was making its closest approach to Uranus, radio contact with Giotto was lost. Lüst was awakened by a 2:00 a.m. call to receive this fact. Several hours later, contact was re-established with some help from the Deep Space Network of NASA, which diverted resources from the tracking of Voyager. "In the interim," Lüst said, "you might imagine my feelings."

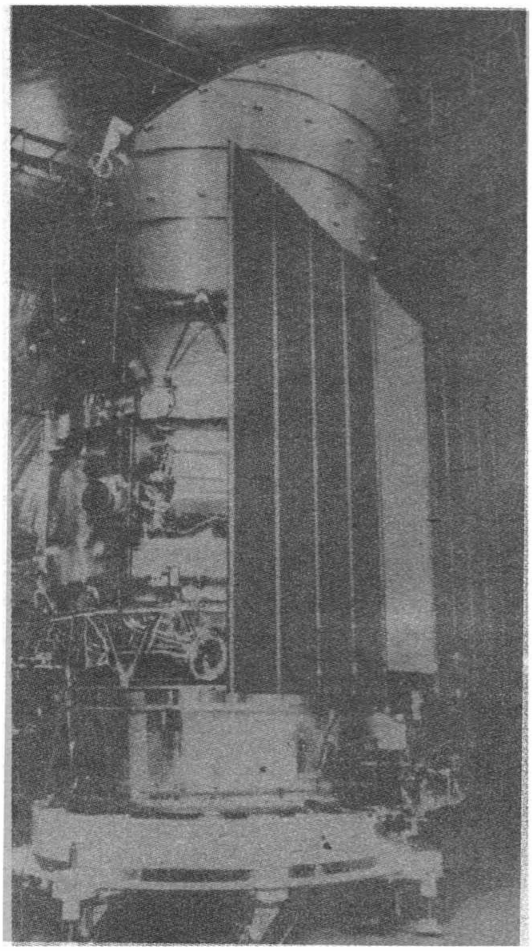
Lüst described the international cooperative effort

INFRA-RED ASTRONOMY



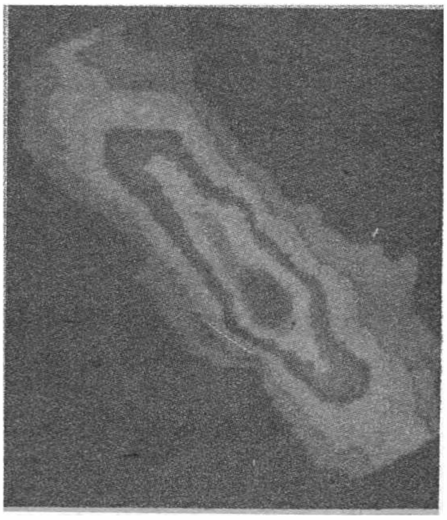
Above: The Infrared Space Observatory (ISO) is an ESA project which is scheduled for operation in 1993. It relies heavily on the experience and results of IRAS for its design and observational planning.

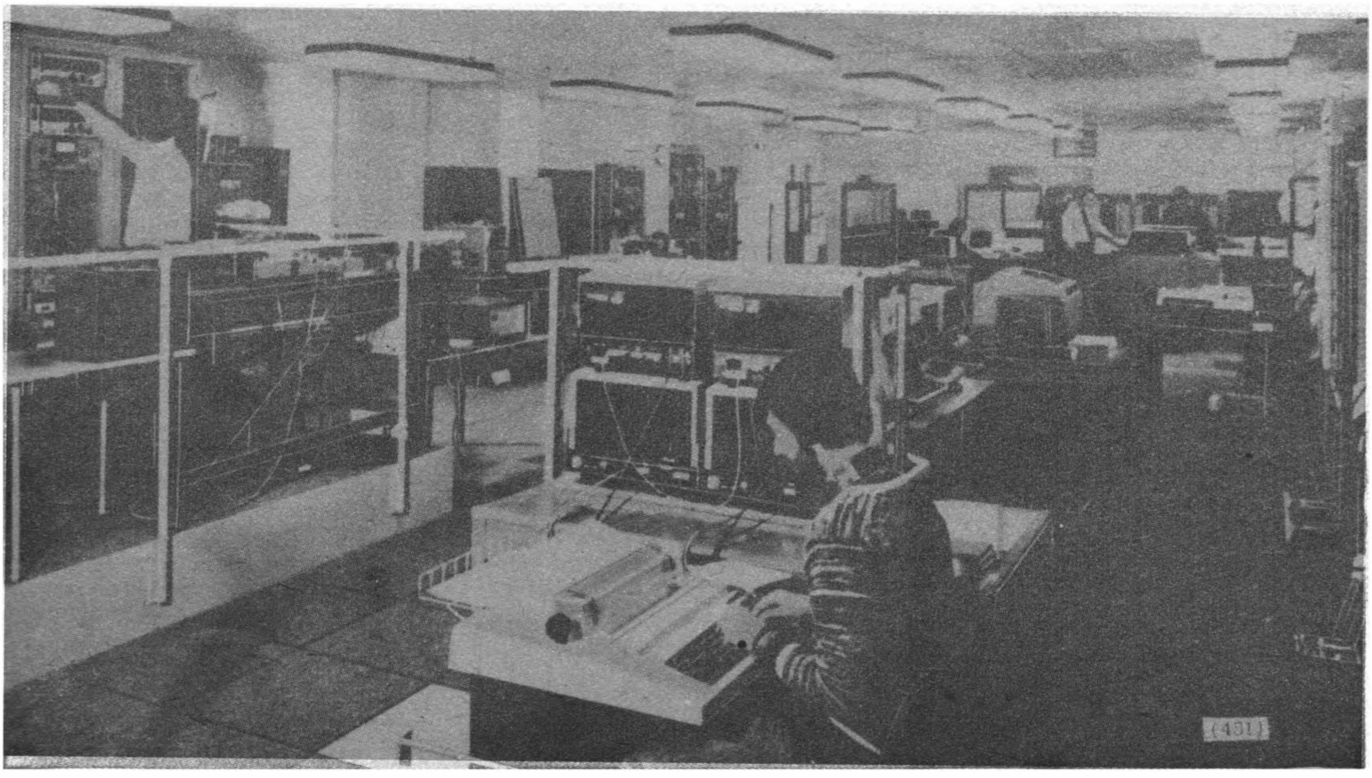
Below: The IRAS Control Centre at the Rutherford Appleton Laboratory, Chilton, Oxfordshire which monitored the status of the satellite and collected data as it passed over the Centre at least twice each day.



IRAS, the Infra-Red Astronomical Satellite, was operational in 1983 and surveyed the whole sky at infrared wavelengths twice plus 70 per cent of it a third time. The project involved groups from the UK, the Netherlands and JPL. Dr. McLaughlin writes on p.454 about observations of galaxies by IRAS and about his recent visit to the Rutherford-Appleton Laboratory with whom JPL has worked on common projects including IRAS.

IRAS is shown on the left under laboratory test. Below is an IRAS map of galaxy NGC 4565 at 100μm wavelength. The angular dimension of the galaxy is about one third of a degree.





Members of the ESA Giotto team.

which enabled Giotto to navigate to within 605 ± 8 km of the nucleus of Halley's comet (see the July/August edition of this column for details). During the period of close approach to the comet, while applause at the results to date was ringing through the control room, all transmissions ceased from Giotto for half an hour. It turned out that the spacecraft had encountered a wall of dust, knocking its antenna off Earth point. The nutation dampers gradually restored the geometric configuration, and radio contact resumed.

The scientific results from the Halley fleet were impressive. Some three to five tons per second of dust were observed by the various spacecraft; the rate varied from observer to observer due to rotation of the nucleus. Perhaps one metre of depth would be removed at each apparition. Pictures shown by Lüst revealed one km craters at a resolution of about 100 m. Two major dust jets from the nucleus, which rotates with a 52.9 hr. period, were observed. Infrared measurements revealed a surface temperature of the nucleus in the range of 300 to 400 °K., which is too hot to be ice, hence an insulating layer, or dust crust, is inferred. A comprehensive presentation of scientific results can be obtained from the journal *Nature*, in the May 15, 1986 issue.

Although damaged, Giotto has been redirected back to Earth and is scheduled to arrive on July 2, 1990, five years after launch. If the engineering systems are judged to be sufficient, Giotto might be sent to study Comet Grigg-Skjellerup, arriving on July 14, 1992.

A Visit to RAL

The Rutherford Appleton Laboratory (RAL) in Oxfordshire is a major centre of UK space activity as well as a support for basic research in physics. See the July 1984 special issue of *JBIS* for an in-depth review of its space-related projects.

The RAL/JPL connection is one of affinity; both institutions have deep roots in space science, and, of a more direct nature, have worked on common projects such as IRAS and AMPTE.

It was a pleasure for me to return for a visit to RAL almost three years after the conclusion of IRAS operations from that site. Visible reminders of that highly successful infrared explorer are present, from the white 12m antenna out front to colourful representations of the infrared sky decorating offices and hallways.

Some of the buildings we used during operations have been removed, but their presence was still palpable for me through memory of the early days in 1983 when the UK, Dutch and US engineers and scientists worked hard to check out the newly launched satellite

and commence the all-sky survey.

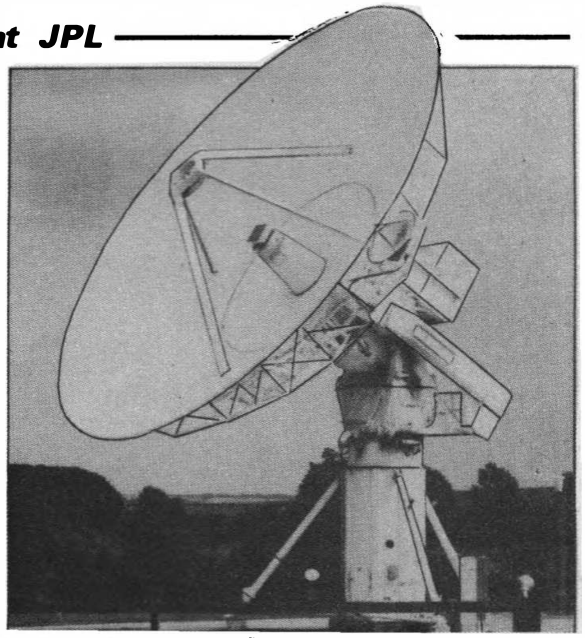
It was good to be able to renew acquaintances with colleagues who shared the trenches, such as John MacDougall and Jock Gourlay, and to sit down for conversations with Dr. Eric Dunford and Dr. Richard Holdaway. Dunford manages the Satellite Control and Data processing Group and Holdaway leads the Astrodynamics Section within Dunford's group.

Some reorganisation within RAL is foreseen as a response to the formation of the British National Space Centre (BNSC), and in the long term, it is felt that the Laboratory's programmes should benefit substantially from this new national emphasis on space. The Royal Aircraft Establishment, Farnborough, is also planned to be a component in the BNSC. Its emphasis on remote sensing and other applications will complement RAL's primarily scientific programmes.

Projects are the lifeblood of a space organisation. The Rutherford Appleton Laboratory can look back to its work on IRAS, AMPTE, IUE, UK satellites (the last was Ariel 6), and others.

Current work includes ROSAT, an astronomical satellite designed to do an all-sky survey in the extreme ultraviolet portion of the electromagnetic spectrum. The original launch plan was to employ a Shuttle in 1987 for the ascent to Earth orbit, but the Challenger accident in January has forced the exploration of alternative means. One possibility is to utilise an existing Atlas-Centaur launcher, if one can be obtained, or one newly off the production line for a launch in the 1989 time frame. The ground data system for UK applications is being developed by RAL; operations for ROSAT will be conducted at the Space Operations Center (GSOC) at Oberpfaffenhofen, Federal Republic of Germany.

A second project of considerable interest is ESA's Infrared Space Observatory (ISO), which will build upon the heritage of IRAS and is scheduled for launch about 1993. The RAL effort includes data analysis and work on the long-wavelength spectrometer, photometer, and near-infrared camera.



The Ground Station antenna at RAL.

Among other project involvements are: The Hubble Space Telescope, Columbus (the European contribution to Space Station), and Technology Satellite (TSAT) – a mobile communications research effort. RAL manages STARLINK, a distributed processing network for astronomy which serves major university centres within Britain.

The Laboratory's space-support levels met with a staff cut after IRAS, and, along with the current hiatus in launches, Dunford and other managers face, like their counterparts at JPL, a challenge to retain the appropriate skills within their organisations. The importance of experienced people to the conduct of a space mission cannot be overemphasised. But, if the past is any guide, we expect both the English and the American laboratories to enter the 1990s in a strong position to carry on their traditions in space science.

A portion of the Milky Way is shown in this IRAS image, extending from longitude 110° to 140° and latitude +13° to -13°. The coldest regions are red and the warmer regions are blue. The bluish loop structures, at the greatest longitude in the image, are IC1795, IC1805, and IC1848. The greenish circular object is NGC1822. The resolution of this image is six arc minutes. *NASA/JPL*

IRAS and Galaxies

The Infrared Astronomical Satellite (IRAS), which in 1983 conducted a 300-day survey of the celestial sphere in the infrared, observed 250,000 point sources and 25,000 galaxies. The catalogue of point sources (principally stars) has been issued, but analysis of the cornucopia continues at the Infrared Processing and Analysis Center at Caltech and within the astronomical community at large.

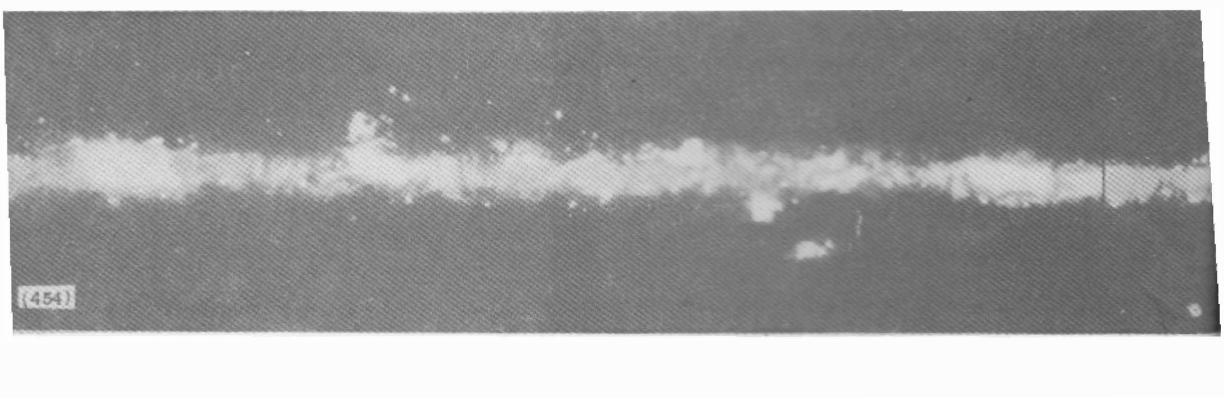
On October 10 in London, Professor Gerry Neugebauer gave the George Darwin Lecture of the Royal Astronomical Society on the topic, "IRAS and the IRAS view of the Extragalactic Sky". The lecture presented an overview of the picture of the infrared universe that is emerging as a result of IRAS.

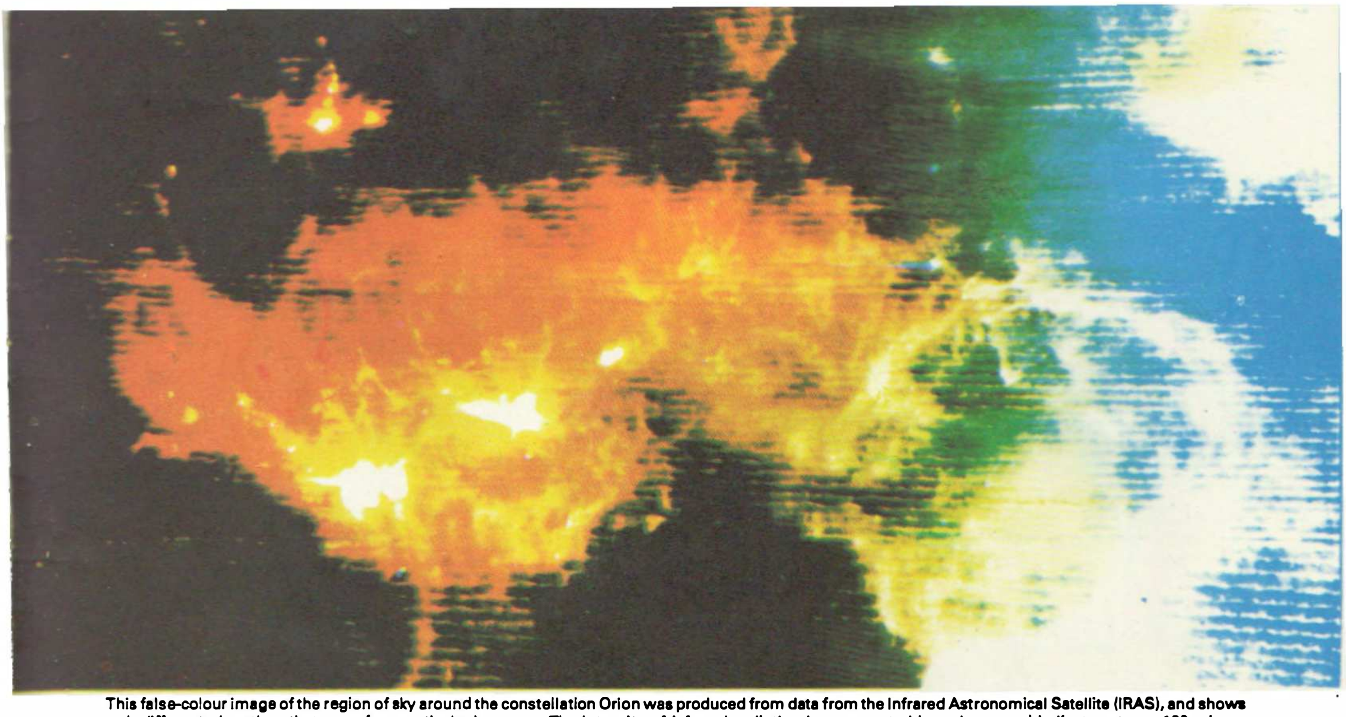
Neugebauer, a professor of physics at Caltech, is the Director of Palomar Observatory and served as the lead US scientist for IRAS. He is one of the pioneers of infrared astronomy, having completed (with his colleague R.B. Leighton) the first survey, an Earth-based one, of the infrared sky. This survey, published in 1969, was conducted in the wavelength region of 2μm, where the Earth's atmosphere is reasonably transparent to infrared radiation. A micron (μm) is one millionth of a metre, and "infrared" is normally taken to designate electromagnetic waves whose lengths go from 0.7μm to 1000μm (one millimeter). Visible light spans 0.4μm to 0.7μm.

Neugebauer said that there are two primary reasons for working in the infrared. First, it allows a good look at cool objects (room temperature is typical of a "cool" object in the astrophysical sense, as opposed to a hot object like a star). An important class of cool objects consists of structures created during the process of star formation, prior to ignition of thermonuclear energy sources. Second, one can see well in the infrared in the sense that the extinction of infrared is much less than that of visible light.

Sources of infrared energy include stars, black holes which accelerate electrons, and starbursts. The last item refers to formation of a large number of stars from a cloud of dust and gas in a very short period of time. Dust, asteroids, comets, etc. are secondary sources of infrared photons: they absorb energy in the ultraviolet and visible and re-radiate it in the infrared.

Previously, the problems of conducting a survey in the infrared were twofold: the Earth's atmosphere absorbs most infrared radiation from celestial sources, except in a few wavelength bands, and the technology of infrared detectors lagged far behind that of, say, mirror making for visible-wavelength astronomy. As a consequence, most infrared astronomy consisted of looking at objects discovered by astronomers at visible or radio wavelengths.





This false-colour image of the region of sky around the constellation Orion was produced from data from the Infrared Astronomical Satellite (IRAS), and shows a much different view than that seen from optical telescopes. The intensity of infrared radiation is represented by colours: red indicates strong 100-micron wavelength radiation, green indicates strong 60-micron wavelength radiation, and blue shows strong 12-micron wavelength radiation. *NASA*

All this was changed by IRAS, characterised by Neugebauer as "a thermos jug containing a telescope" – the telescope had to be cooled by liquid helium so that infrared photons from the instrument itself would not overwhelm the astronomical data. At an altitude of 900 km above Earth, the satellite avoided atmospheric-extinction problems and was equipped with an array of 62 highly sensitive infrared detectors, placed in the focal plane of the relatively small (57cm diameter) telescope. The detectors were of four types with the mid-point of their wavelength sensitivities at 12μm, 25μm, 60μm, and 100μm.

Of the 25,000 galaxies detected by IRAS (out of the perhaps 10^{11} galaxies in the universe), about 500 were seen as extended, (ie, not as just a point source) and a dozen or so, including, of course, the nearby Andromeda Galaxy (M31), were of large enough apparent size so that internal structure could be observed. Galaxies were seen distant enough to be receding at 40 per cent of the speed of light in this expanding universe where, according to Hubble's law, the rate of recession increases with distance from the observer.

IRAS observed galaxies over an extremely wide range of luminosities: from 10^6 times to 10^{13} times the brightness of the Sun. A major discovery of IRAS was that at high luminosities the universe has more IRAS-observed galaxies than quasars. The result is important because it adds to our knowledge of the inventory of fundamental objects in the universe.

The ultraluminous galaxies observed by IRAS can be characterised by five properties: (1) there are a lot of them, (2) they contain considerable quantities of gas in their interstellar reaches, (3) starburst activity and energetic nuclei are frequently seen, (4) evidence that the object may be two merged galaxies is often present, and (5) these galaxies show a high ratio of infrared-to-visible radiation.

These properties led Neugebauer to speculate that some quasars are evolved from two merged galaxies, which first form an ultraluminous galaxy as described above, then, after much of their gas has been lost and a black hole has developed in the nucleus, they are recognised as quasars. He emphasised that further work would have to be done in order to verify or reject this intriguing hypothesis.

This IRAS image, shows 90° along the plane of our Galaxy (the Milky Way). The centre of our Galaxy is located at the brightest spot. The large, nearly circular structure (right) shows emission from the Galactic plane in the vicinity of the constellation Cygnus. *NASA/JPL*